

THE PALAEOLOGY AND STRATIGRAPHY
OF THE LOWER PART OF THE UPPER
KIMMERIDGE CLAY OF DORSET

BY

J. C. W. COPE *J.C.W.*

Department of Geology, University College, Swansea

Pp. 1-79; 33 *Plates*; 12 *Text-figures*

BULLETIN OF
THE BRITISH MUSEUM (NATURAL HISTORY)
GEOLOGY

Vol. 15 No. 1

LONDON: 1967



THE BULLETIN OF THE BRITISH MUSEUM (NATURAL HISTORY), instituted in 1949, is issued in five series corresponding to the Departments of the Museum, and an Historical series.

Parts will appear at irregular intervals as they become ready. Volumes will contain about three or four hundred pages, and will not necessarily be completed within one calendar year.

In 1965 a separate supplementary series of longer papers was instituted, numbered serially for each Department.

This paper is Vol. 15, No. 1 of the Geological (Palaeontological) series. The abbreviated titles of periodicals cited follow those of the World List of Scientific Periodicals.

World List abbreviation
Bull. Br. Mus. nat. Hist. (Geol.).

© Trustees of the British Museum (Natural History) 1967

TRUSTEES OF
THE BRITISH MUSEUM (NATURAL HISTORY)

Issued 26 May, 1967

Price £4 15s.

THE PALAEOONTOLOGY AND STRATIGRAPHY OF THE LOWER PART OF THE UPPER KIMMERIDGE CLAY OF DORSET

By J. C. W. COPE

CONTENTS

	<i>Page</i>
I. INTRODUCTION	4
II. THE KIMMERIDGE SECTION	5
III. THE NON-AMMONITE FAUNA	10
IV. THE AMMONITE FAUNA	11
(a) INTRODUCTION	11
(b) SYSTEMATIC DESCRIPTIONS	12
Genus <i>Gravesia</i> Salfeld	12
<i>Gravesia gigas</i> (Zieten)	12
<i>G. cf. gravesiana</i> (d'Orbigny)	14
Genus <i>Pectinatites</i> Buckman	14
Sexual Dimorphism	15
Interpretation of <i>Pectinatites</i>	18
The Origins of <i>Pectinatites</i>	22
Subgenus <i>Arkelites</i> nov.	24
<i>Pectinatites (Arkelites) primitivus</i> sp. nov.	24
<i>P. (A.) cuddlensis</i> sp. nov.	26
<i>P. (A.) damoni</i> sp. nov.	28
<i>P. (A.) hudlestoni</i> sp. nov.	29
Subgenus <i>Virgatosphinctoides</i> Neaverson	30
<i>Pectinatites (Virgatosphinctoides) elegans</i> sp. nov.	31
<i>P. (V.) elegans corniger</i> subsp. nov.	33
<i>P. (V.) scitulus</i> sp. nov.	34
<i>P. (V.) decorosus</i> sp. nov.	36
<i>P. (V.) major</i> sp. nov.	37
<i>P. (V.) clavelli</i> sp. nov.	39
<i>P. (V.) smedmorensis</i> sp. nov.	41
<i>P. (V.) laticostatus</i> sp. nov.	43
<i>P. (V.) grandis</i> (Neaverson)	44
<i>P. (V.) grandis acceleratus</i> subsp. nov.	45
<i>P. (V.) woodwardi</i> (Neaverson)	45
<i>P. (V.) wheatleyensis</i> (Neaverson)	46
<i>P. (V.) wheatleyensis minor</i> subsp. nov.	47
<i>P. (V.) wheatleyensis delicatulus</i> (Neaverson)	48
<i>P. (V.) pseudoscruposus</i> (Spath)	49
<i>P. (V.) reisiiformis</i> sp. nov.	50
<i>P. (V.) reisiiformis densicostatus</i> subsp. nov.	53
<i>P. (V.) abbreviatus</i> sp. nov.	54
<i>P. (V.) donovani</i> sp. nov.	55
<i>P. (V.) magnimasculus</i> sp. nov.	56
<i>P. (V.) encombensis</i> sp. nov.	57

	Page
Subgenus <i>Pectinatites</i> Buckman	59
<i>Pectinatites</i> (<i>Pectinatites</i>) <i>inconsuetus</i> sp. nov.	59
<i>P. (P.) eastlecottensis</i> (Salfeld)	60
<i>P. (P.)</i> cf. <i>groenlandicus</i> (Spath)	61
<i>P. (P.) cornutifer</i> (Buckman)	62
<i>P. (P.) naso</i> (Buckman)	62
Genus <i>Pavlovia</i> Ilovaisky, subgenus <i>Paravirgatites</i> Buckman	63
<i>Pavlovia</i> (<i>Paravirgatites</i>) cf. <i>paravirgatus</i> (Buckman)	63
V. EVOLUTION OF THE AMMONITES	64
VI. THE AMMONITE ZONES	66
<i>Pectinatites</i> (<i>Virgatosphinctoides</i>) <i>elegans</i> Zone	66
<i>P. (V.) scitulus</i> Zone	68
<i>P. (V.) wheatleyensis</i> Zone	69
<i>P. (Arkelites)</i> <i>huddlestoni</i> Zone	69
<i>P. (Pectinatites)</i> <i>pectinatus</i> Zone	70
VII. CORRELATIONS	70
(a) Great Britain	70
(b) The Boulonnais	72
(c) East Greenland (Milne Land)	73
(d) Southern Germany (Franconia)	73
(e) Russia (Basin of the Ural and Ilek Rivers)	75
VIII. REFERENCES	76

SYNOPSIS

Re-examination of the lower part of the Upper Kimmeridge Clay of the type section at Kimmeridge, Dorset, has involved detailed collecting and re-measurement of the succession. The ammonite fauna of some 465 ft. of these beds is described.

The ammonites belong to three subfamilies; three genera are represented, and descriptions are given of three subgenera (one new); twenty-eight species (seventeen new); and five subspecies (four of them new).

Sexual dimorphism is recognized in one genus, and is believed to be of a unique type.

A revised zonal scheme is proposed, and correlations are suggested with Northern France, Greenland, and other areas of Britain.

Comparisons are made with the ammonite fauna of other extra-British areas. The fauna of the Lower Tithonian rocks of Germany is shown to be quite distinct from that of the Upper Kimmeridgian of Britain, such similarities as exist being entirely due to homeomorphy.

I. INTRODUCTION

EXISTING knowledge of the Upper Kimmeridgian ammonite faunas of Britain is very imperfect. The research work which forms the basis of this account is the first stage of a planned research project, in the course of which it is proposed to study these rocks and their faunas over the whole of Britain.

The lower Kimmeridgian fauna of Britain is comparatively well known and it was, therefore, considered that the best way to carry out this work was to begin at the base of the Upper Kimmeridgian (the base of the present *Gravesia* Zones) and work upwards to the Portlandian.¹ The scope of the first part of the work embraces the *Gravesia*, "*Subplanites*" and basal *Pectinatites* Zones of the type-section.

¹ The Middle Kimmeridgian of Arkell (1956: 21) has, as a result of the conclusions presented herein, no real standing. It seems most appropriate to have, therefore, two subdivisions of the Kimmeridgian Stage, the line between them being drawn at the top of the *Aulacostephanus autissiodorensis* Zone.

Prior to 1913 most of the ammonites from the British Upper Kimmeridgian were known under the name of *Ammonites biplex*—a name which embraced practically all Upper Jurassic perisphinctid ammonites.

In 1913 Salfeld identified some of the British Upper Kimmeridgian ammonites with Pavlov's genus *Virgatites*. Neaverson (1925) showed that these ammonites were not related to the Russian Volgian forms as Salfeld had supposed. Neaverson's work, valuable though it was, fell far short of monographing the whole ammonite fauna from these beds. Neaverson did not undertake comprehensive collecting from the type-section in Dorset, which surely must be the basis for zonal subdivision. The sequence there is a thick one, and as far as is known, complete. In contrast, the sections in the Oxford district, taken by Neaverson as the basis for his zonal scheme, are incomplete and very much attenuated. As a result, parts of his zonal scheme are unsatisfactory.

Spath in the early 1930's made a collection from the Kimmeridge section (now housed in the British Museum (Natural History)), and although this was never described, references are made to it in several of his papers (e.g. 1935 : 73). He identified Neaverson's genera *Allovirgatites* and *Virgatosphinctoides* with his genus *Subplanites*, proposed in 1925 for a group of ammonites occurring in Franconia; he later identified other British forms with the Tithonian genus *Lithacoceras*; and as a result, correlations became established between Britain and Germany based on these genera. These correlations were followed among others by Arkell (1956), and have now become generally accepted.

The collections from Dorset now to be described, however, establish beyond doubt that the British Upper Kimmeridgian and German Tithonian forms are not identical, and these previous correlations are thus without real value.

Many colleagues and friends have been of invaluable assistance in providing helpful suggestions and criticisms. I am particularly indebted in this respect to Professor D. T. Donovan, Dr. J. H. Callomon, and Dr. A. Zeiss.

The receipt of a Research Studentship from the former Department of Scientific and Industrial Research, a grant from the British Council under the Younger Research Workers Interchange Scheme, and financial assistance from the University College of Swansea are gratefully acknowledged.

II. THE KIMMERIDGE SECTION

The Kimmeridge Clay is the oldest formation exposed on the Isle of Purbeck. It appears as a long strip, approximately six miles in length and usually less than a mile wide, in the core of the Purbeck Anticline. To the north the steep escarpment of the Portland Stone effectively isolates this relatively low-lying land. The village of Kimmeridge is situated in a hollow beneath this escarpment.

The outcrop of the Kimmeridge Clay on the northern limb of the Purbeck Anticline occurs in a military zone extending five miles westwards from Kimmeridge, and is for this reason inaccessible. Eastwards from Kimmeridge Bay, however, the section is well displayed for over three miles on the southern limb of the anticline. The sea erodes at a substantial rate the relatively soft shales which comprise the bulk of the succession, but has little effect on the occasional cementstone bands which stretch

out from the base of the cliffs to form the Kimmeridge Ledges, presenting a considerable hazard to shipping.

The cliffs, which are seldom more than 150 ft. in height, are precipitous and crumbling. A constant trickle of shale debris down the cliffs builds up piles of talus at their foot. Occasional larger falls bring down large pieces of the cementstone bands which litter the shore at the cliff base, and break the force of the waves. It is generally only at high spring tides that the sea can reach the foot of the cliffs.

At the foot of the beach at low tide small ledges or reefs of shale are exposed, and these are the only places where fossils can be satisfactorily collected.

The part of the Kimmeridge section described herein embraces parts of the Kim-

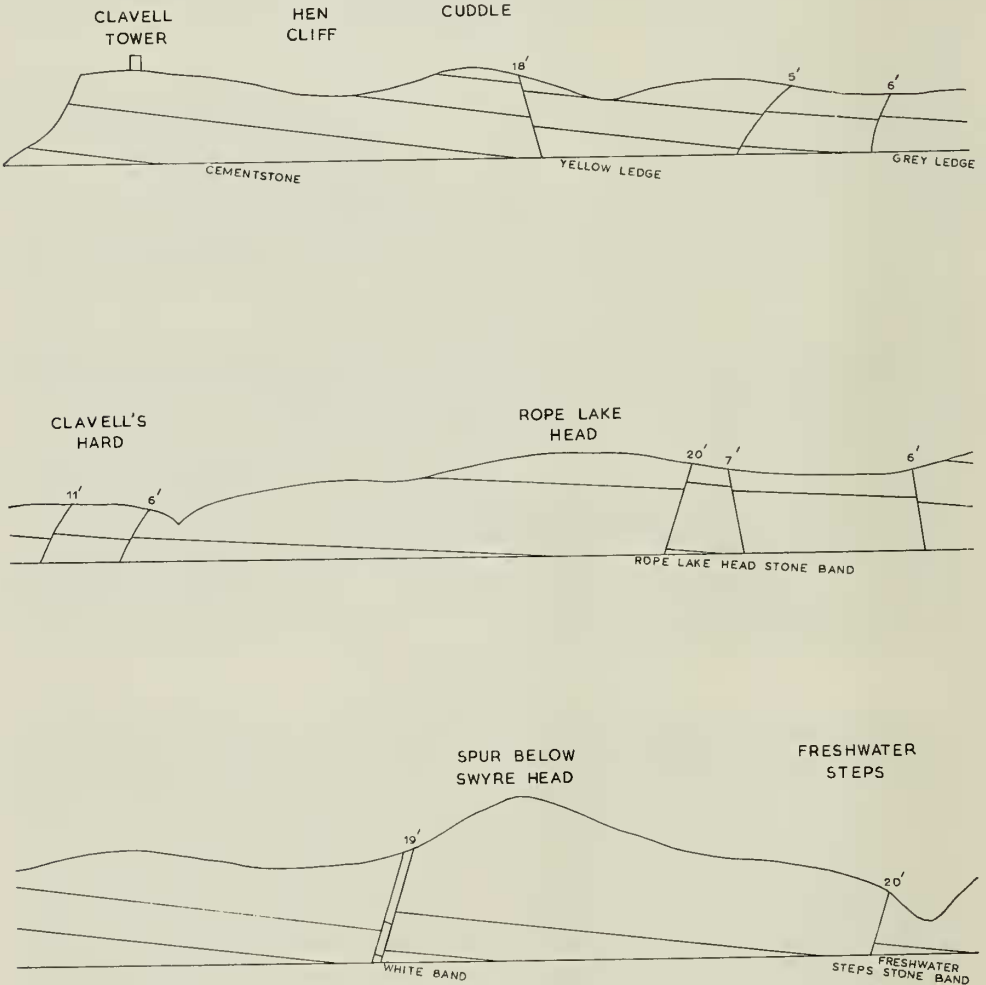


FIG. 1. Section of the cliffs from the eastern end of Kimmeridge Bay to Freshwater Steps. Modified after Arkell 1947 : 75.

meridge Clay, whose faunas have hitherto been very imperfectly known. The lowest horizon from which collections have been made is the cementstone band which forms a prominent reef on the foreshore at the western end of Hen Cliff. This bed marks, in the Kimmeridge section, the top of the *Aulacostephanus autisiodorensis* Zone, and therefore forms the junction between the Lower and Upper Kimmeridge Clay. The highest horizon studied is some twenty feet above the Freshwater Steps Stone Band. It is proposed to describe, at a later date, the highest beds of the Kimmeridge Clay, lying above this latter horizon and upwards to the Portlandian rocks.

This section has been re-measured in detail, using direct measurement where possible, supplemented by data acquired using an Abney level to measure the thicker lithological units, and to fix the position of the shale ledges relative to the nearest marker horizon.

The system of bed numbering used is that of Blake (1875 : 198-199) who was the first to make a detailed description of this section. Although Blake numbered his beds from the top downwards (thus Bed 1 was the last to be deposited), his bed numbers are for the most part well-defined. It was found that Blake's measurements were substantially correct, but there are several quite considerable errors, some being perpetuated by Arkell (1947 : 71-72).

In the description given below, only major lithological units are described. The stratigraphical range of a species may be found more accurately by reference to the systematic description of the species, or the section on the zonal stratigraphy.

Blake's Bed Number		ft.	in.
	<i>Pectinatites (Pectinatites) pectinatus</i> Zone		
9	Shales	20	0
	<i>Pectinatites (Pectinatites) naso</i> , <i>P. (P.) cornutifer</i> , <i>Pavlovia (Paravirgatites) paravirgatus</i> , <i>Ostrea bononiae</i> , <i>Discina latissima</i> .		
10	Freshwater Steps Stone Band	1	3
11	Shales	29	0
	<i>Pectinatites (Pectinatites) cornutifer</i> , <i>P. (P.) groenlandicus</i> , <i>P. (P.) eastlecottensis</i> , <i>P. (P.) inconsuetus</i> , <i>Ostrea bononiae</i> , <i>O. solitaria</i> , <i>Protocardia morinica</i> , <i>Discina latissima</i> .		
12 pars	Middle White Stone Band	1	6
12 pars-	Shales and mudstones	29	4
20 pars	<i>Pectinatites (Pectinatites) cf. eastlecottensis</i> , <i>P. (?Arkelites) sp. indet.</i> , <i>Ostrea sp.</i>		
20 pars	White Stone Band	3	0

Blake's Bed Number		ft.	in.
	<i>Pectinatites (Arkellites) hudlestoni</i> Zone		
20 pars	Shales, mudstones, hard "dicey" bands	51	8
-23	<i>Pectinatites (Virgatosphinctoides) encombensis</i> , <i>P. (V.) magnimasculus</i> , <i>P. (Arkellites) hudlestoni</i> , <i>Lucina miniscula</i> , <i>Protocardia morinica</i> , <i>Ostrea bononiae</i> , <i>Discina latissima</i> , <i>Ichthyosaurus</i> sp.		
24	Basalt Stone Band	3	10
	<i>Inoceramus expansus</i> , <i>Ostrea</i> sp.		
25	"Dicey" mudstones	55	0
	<i>Pectinatites (Virgatosphinctoides) donovani</i> , <i>Inoceramus expansus</i> , <i>Parallelodon</i> sp.		
26 pars	Shales	13	1
	<i>Pectinatites (Arkellites) hudlestoni</i> , <i>P. (Virgatosphinctoides) reisiiformis</i> , <i>P. (V.) reisiiformis densicostatus</i> , <i>P. (V.) cf. reisiiformis</i> , <i>P. (V.) abbreviatus</i> , <i>P. (V.) grandis acceleratus</i> , <i>Ostrea bononiae</i> , <i>Ostrea multiformis</i> , <i>Ostrea</i> sp., <i>Protocardia</i> sp., <i>Discina latissima</i> .		
26 pars	Cementstone		4
26 pars	Shales	8	11
	<i>Pectinatites (Virgatosphinctoides) reisiiformis</i> , <i>Ostrea bononiae</i> , <i>Ostrea</i> sp.		
26 pars	Rope Lake Head Stone Band	1	6
	<i>Pectinatites (Virgatosphinctoides) wheatleyensis</i> Zone		
26 pars	Shales	14	7
	<i>Pectinatites (Virgatosphinctoides) reisiiformis</i> , <i>P. (V.) wheatleyensis delicatulus</i> , <i>P. spp. indet.</i> , <i>Ostrea</i> sp.		
26 pars	The Blackstone, or Kimmeridge Oil Shale	2	10
	<i>Pectinatites (Virgatosphinctoides) wheatleyensis delicatulus</i> , <i>P. spp. indet.</i> , <i>Saccocoma</i> sp., <i>Ostrea</i> sp., <i>Discina latissima</i> , <i>Lepidotus</i> sp.		
27 pars	Shales	13	6
	<i>Pectinatites (Virgatosphinctoides) wheatleyensis</i> , <i>P. (V.) wheatleyensis delicatulus</i> , <i>P. (V.) grandis</i> , <i>P. (V.) pseudoscruposus</i> , <i>P. (V.) cf. pseudoscruposus</i> , <i>P. (V.) laticostatus</i> , <i>P. (V.) woodwardi</i> , <i>Saccocoma</i> sp., <i>Ostrea bononiae</i> , <i>Protocardia morinica</i> , <i>Lucina miniscula</i> , <i>Discina latissima</i> , <i>Lingula ovalis</i> , <i>Cerithium</i> sp.		
27 pars	Siltstone		1
27 pars	Shales	2	3
	<i>Pectinatites (Virgatosphinctoides) laticostatus</i> , <i>P. (V.) woodwardi</i> , <i>P. (V.) wheatleyensis</i> , <i>P. (V.) grandis</i> .		

Blake's Bed Number		ft.	in.
27 pars	Siltstone <i>Pectinatites (Virgatosphinctoides) laticostatus, Discina latissima.</i>		1
27 pars	Shales <i>Pectinatites (Virgatosphinctoides) grandis, P. (V.) wheatleyensis minor, Ostrea sp.</i>	1	10
28-30	"Dicey" mudstones and shales <i>Pectinatites (Virgatosphinctoides) laticostatus, P. (V.) smedmorensis, P. (V.) clavelli, Ostrea bononiae, Protocardia morinica, Lingula ovalis.</i>	45	5
31	Grey Ledge Stone Band (Top Ledge of Spath)	2	3
<i>Pectinatites (Virgatosphinctoides) scitulus</i> Zone			
32-33	Upper Cattle Ledge Shales		
32	"Dicey" mudstones <i>Ostrea sp.</i>	18	5
33	Shales <i>Ophthalmosaurus sp.</i>	17	5
34	Cattle Ledge Stone Band <i>Pectinatites (Virgatosphinctoides) cf. major.</i>	1	8
35	Lower Cattle Ledge Shales <i>Pectinatites (Virgatosphinctoides) scitulus, P. (V.) cf. scitulus, P. (V.) decorosus, P. (V.) major, P. (V.) cf. major, P. (Arkelites) cuddlensis, P. (A.) damoni, Gravesia cf. gravesiana, Ostrea bononiae, O. multiformis, Protocardia morinica, Lucina miniscula, Modiola autissiodorensis, Exogyra virgula, Lingula ovalis, Discina latissima, Cerithium sp., Pliosaurus sp., Thrissops sp.</i>	51	5
36	Yellow Ledge Stone Band <i>Pectinatites (Arkelites) cuddlensis, P. (Virgatosphinctoides) elegans corniger, P. (V.) cf. scitulus.</i>	1	6
<i>Pectinatites (Virgatosphinctoides) elegans</i> Zone			
37- 41 pars	Hen Cliff Shales <i>Pectinatites (Virgatosphinctoides) elegans, P. (V.) elegans corniger, P. (V.) major, P. (V.) cf. major, P. (Arkelites) cuddlensis, P. (A.) primitivus, P. sp. indet., Gravesia gigas, G. cf. gravesiana, Ostrea bononiae, Ostrea multiformis, Ostrea sp., Exogyra virgula, Trigonina pellati, Protocardia morinica, Lucina miniscula, Modiola autissiodorensis, Lingula ovalis.</i>	69	3

Blake's Bed Number		ft.	in.
41 pars	Cementstone	I	0
41 pars	Shale <i>Pectinatites (Arkellites) cf. primitivus.</i>	I	II
42	Cementstone <i>Pectinatites (Arkellites) cf. primitivus.</i>		8
TOTAL THICKNESS		464	6

III. THE NON-AMMONITE FAUNA

The non-ammonite fauna, although often abundant in terms of individuals, is represented by few species.

VERTEBRATA

PISCES. Fish remains are common throughout the succession, but consist mainly of isolated scales. Fish scales are exceedingly abundant in the *Pectinatus* Zone. Identifiable fish remains include *Thrissops* sp., and *Lepidotus* sp.

REPTILIA. Vertebrae and occasionally other bones occur quite commonly. The anterior part of a skeleton of *Ophthalmosaurus* was found 12 ft. above the Cattle Ledge Stone Band, and a skull of *Ichthyosaurus* from 12 ft. below the White Stone Band. A posterior tooth of a Pliosaur was found 5 ft. above the Yellow Ledge Stone Band.

BRACHIOPODA

Discina latissima (Sow.) occurs throughout, but is more common above the Blackstone Band.

Lingula ovalis Sow. also ranges through the succession, but appears to reach its maximum just above the Yellow Ledge Stone Band.

ECHINODERMATA

One species of crinoid (*Saccocoma* sp.) occurs as isolated pyritized plates. It appears to be confined to the Blackstone and the ten feet of shale immediately below.

MOLLUSCA

GASTROPODA: Species of *Cerithium* have been found 27 ft. above the Yellow Ledge Stone Band, and 3 ft. below the Blackstone; apart from these occurrences no other gastropods were recorded.

BIVALVIA: Bivalves are the most abundant of the non-ammonite fauna. *Exogyra virgula* (Defrance) occurs up to 27 ft. above the Yellow Ledge Stone Band.

Protocardia morinica (de Loriol) and *Lucina miniscula* Blake are abundant throughout.

Ostrea bononiae Sauvage and *O. multiformis* Koch & Dunker, commonly occur attached to the undersurfaces of ammonite shells.

Other bivalves include *Trigonia pellati* Mun-Chal., *Parallelodon* sp., *Inoceramus expansus* Blake, *Ostrea solitaria* Sow., and *Modiola autissiodorensis* (Cott.)

Nautiloids and belemnites are absent from the fauna.

IV. THE AMMONITE FAUNA

(a) INTRODUCTION

The state of preservation of the ammonites from the Kimmeridge section leaves much to be desired from the point of view of palaeontological investigations.

The nodule bed in the Rotundum Zone of the Kimmeridge Clay is well known as one horizon which yields reasonably well preserved uncrushed ammonites. The author has found uncrushed, or relatively uncrushed, specimens at two other horizons, both of them in the part of the section described herein. One large isolated nodule 25 ft. below the Yellow Ledge Stone Band yielded a few pyritized ammonite nuclei, none of which are determinable specifically. The other horizon, the roof bed of the Blackstone, yields ammonites preserved in solid pyrite, but in which, unfortunately, the septa have been completely pyritized and have become destroyed.

All the other ammonites from other horizons have suffered crushing to a high degree. The ribbing, however, is generally well preserved, and is the basis for identification. The suture has almost invariably been completely obliterated.

Considerable problems have had to be surmounted both in the collection and the preparation of these ammonites. Fossils cannot be collected from the cliffs, owing to the fissile nature of most of the rock, and the consequent weathering of the shale along the bedding. The abundant pyrite has oxidized, and the resulting selenite crystals cover the surface of the bedding planes.

The shale reefs exposed at the base of the beach at low tide are the only places where ammonites can be satisfactorily collected.

At some horizons, because of the very closely-spaced joints in the mudstone bands, it is impossible to extract the ammonites. In this case a plaster cast of the ammonite impression is made in the field. The detail reproduceable with thinly-mixed plaster is excellent, and the casts so obtained are, for most purposes, as satisfactory to work with as the actual ammonites from other horizons.

The ammonites as they are extracted from the rock form most unpromising-looking material from the palaeontological point of view, and careful preparation is necessary before sufficient detail is visible for any determinative work.

The rib interspaces are filled with hard shale, and often the whole ammonite is encrusted with irregular pyrite aggregates. The lower surface of the ammonite (lower surface of the ammonite as it lies in the rock) is very often more or less encrusted with oysters which are impossible to remove successfully.

The crushing of the ammonites has affected most of the original measurements. The diameter has been increased by the flattening of the outer whorls; the whorl height is similarly affected, whilst the whorl thickness is reduced to about one-eighth of the original dimension. The diameter of the umbilicus is, however, relatively

unchanged. The crushing of the outer whorl has the effect of making the point of bifurcation of the ribs appear much lower on the whorl side than it is in reality.

For purposes of identification and speciation, therefore, the conventional four measurements are not given (i.e. diameter, then the other three measurements expressed as a percentage of the diameter). Instead the diameter and the umbilical diameter only are given. These are both given as measurements since, as mentioned above, the diameter has been increased by the crushing.

Also given, where possible, are the number of primary and secondary ribs on the outer whorl, and the number of ribs at various diameters (usually at 5 mm. intervals) within the umbilicus.

In most cases the macroconch of a species is designated as the holotype. Where this is not possible (i.e. when the macroconch of a species has not been found, or when no well-preserved macroconch has been obtained), the microconch is designated as the holotype.

In cases where the collection of specimens can only be carried out by the making of plaster casts in the field, the macroconch casts have, not infrequently, very much obscured inner whorls. The reason for this is that the casts are made of the under-surface of the ammonites as they lie in the rock, and these under-surfaces are often encrusted with oysters.

(b) SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA

Class CEPHALOPODA

Sub-class AMMONOIDEA

Order AMMONITIDA

Superfamily PERISPHINCTACEAE

Family PERISPHINCTIDAE

Sub-family AULACOSTEPHANINAE Spath 1924

Genus *GRAVESIA* Salfeld 1913

Type species by subsequent designation (Roman 1938): *Ammonites gravesianus* d'Orbigny 1850.

Gravesia gigas (Zieten)

(Pl. 1, fig. 1)

1830 *Ammonites gigas* Zieten, pl. 13, fig. 1.

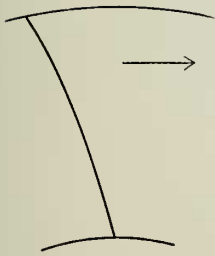
1963 *Gravesia gigas* (Zieten); Hahn: 97, pl. 9, pl. 10, figs. 1, 2 (see also for earlier references).

MATERIAL. Two specimens.

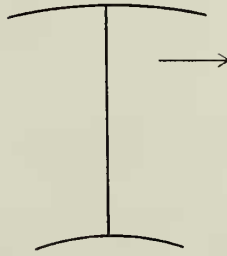
STRATIGRAPHICAL RANGE. 40-45 ft. below the Yellow Ledge Stone Band.

DESCRIPTION. These two specimens, which are similar to one another, are crushed flat. Diameter 308-322 mm. Diameter of umbilicus 104-114 mm. The

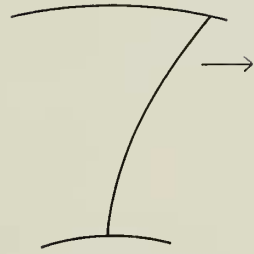
RIB DIRECTION



RURSIRADIATE

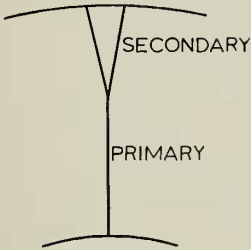


RECTIRADIATE

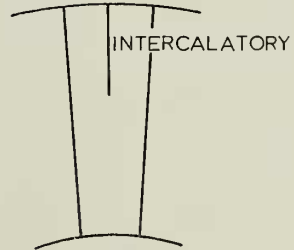


PRORSIRADIATE

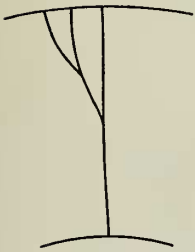
RIB TYPE



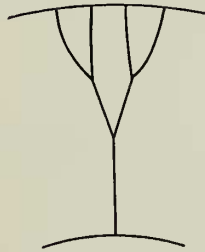
BIFURCATE



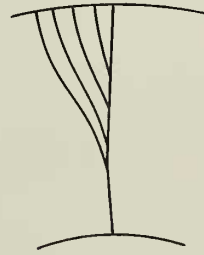
SIMPLE



POLYGYRATE



POLYPLOKE



VIRGATOTOME

FIG. 2. Rib directions and rib types occurring in the ammonites of the Upper Kimmeridge Clay.

original diameter was probably around 240 mm. There is a very close resemblance to the neotype (Hahn 1963, pl. 9, fig. 1), the only discernible difference being that the Dorset specimens still have quite prominent secondary ribs on the venter at the aperture.

REMARKS. This species is extremely rare in Dorset, two other specimens exist in the collections of Spath in the British Museum and are also from the same horizon. Salfeld recorded "numerous examples" of *G. gravesiana* from about this horizon (Arkell 1933 : 440). This species appears, however, to occur higher in the succession.

Gravesia cf. *gravesiana* (d'Orbigny)

(Pl. 1, fig. 2)

1850 *Ammonites gravesianus* d'Orbigny : 559, pl. 219, figs. 1, 2.

1963 *Gravesia gravesiana* (d'Orbigny) ; Hahn : 99, pl. 10, figs. 3, 4 ; pl. 12, figs. 3, 4 ; pl. 13, fig. 2. (See also for earlier references.)

MATERIAL. Two specimens.

STRATIGRAPHICAL RANGE. From 8 ft. below to 6 ft. above the Yellow Ledge Stone Band.

DESCRIPTION. Both the specimens are whorl fragments. The larger (Pl. 1, fig. 2) shows the ribbing very well and is very close to *G. gravesiana*. The total estimated crushed diameter of this specimen would be about 160 mm.

The other specimen shows only three primary ribs, with internal moulds of the secondary ribs, but is similar in rib style to the first specimen.

REMARKS. Salfeld recorded *Gravesia irius* at about this horizon, a species which the author was not able to find.

The occurrence of *Gravesia* above the Yellow Ledge Stone Band has not hitherto been reported, but as this genus is so rare in Dorset it is by no means certain that the newly established range of 60 feet in Dorset is the maximum range of this genus.

Subfamily **VIRGATOSPHINCTINAE** Spath 1923

Genus **PECTINATITES** Buckman 1922

Type species *Ammonites pectinatus* Phillips 1871.

DIAGNOSIS. Dimorphic. Microconchs generally 65–110 mm. in diameter, occasionally larger. Inner whorls with sharp biplicate ribbing, becoming a little coarser on body-chamber with occasional simple and trifurcate ribs. Peristome with ventral horn. Body-chamber generally half a whorl long. Macroconchs generally 140–200 mm. occasionally larger, very rarely smaller. Inner whorls with sharp biplicate ribbing. Outer whorl very variable, usually with strong primary ribs and two to five secondary ribs to each primary rib. Peristome simple. Body-chamber generally half a whorl long. Constrictions present in some species.

Upper Kimmeridgian. (Elegans to Pectinatus Zones).

Sexual Dimorphism

Detailed collecting from the Upper Kimmeridge Clay at the type-section at Kimmeridge, Dorset, has revealed many ammonites referable to species of the genus *Pectinatites* Buckman. Random sampling has established that the vast majority of these fall into one of two size groups. Formerly it has been considered by those who had collected ammonites from this section (e.g. Arkell & Spath), that the smaller specimens were merely young forms of the larger. However, these previous collections consist mostly of individuals from which the peristome had been broken during extraction from the rock, and examination of recent collections, consisting mainly of individuals with peristome intact, suggests a new interpretation of the size grouping. This interpretation arises from the fact that at every horizon from which collections were made, only two size groups are found. The smaller size falls into the 65–110 mm. diameter range, and the larger into the 140–200 mm. diameter range. If the ammonites of the smaller size group were the young of the larger ones it would be remarkable not to find, at some horizon, ammonites falling into the size range 110–140 mm. diameter. Evidence to show that the two groups are quite distinct follows below.

Callomon (1963 : 25) has summarized the criteria by which an ammonite may be judged to be mature. These are:

- (a) Uncoiling of the umbilical seam.
- (b) Modification of sculpture near the peristome; usually a coarsening and re- or degeneration of ribbing, but often with terminal constrictions, ventral collars, flares, horns, rostra, lateral lappets etc.
- (c) Approximation and degeneration of the last few septal sutures.

As the ammonites are badly crushed, all traces of the septa have been destroyed. If, however, the first two of these criteria are applied, it is found that both size groups mentioned above consist of mature individuals.

Species of these perisphinctid ammonites are best distinguished from one another by the density of the ribbing. If the numbers of ribs at given diameters are plotted against diameters on a graph, a curve is produced which is distinctive for any given species. The two size groups under consideration here give generally similar, but not identical curves, so that it is possible to distinguish, by means of rib curves, the larger from the smaller type, even with incomplete material. These two groups have been referred to as microconchs and macroconchs by Callomon (1957 : 62), a terminology which has become generally accepted.

The microconchs, in this case, are generally small forms with a diameter of 65–110 mm., but at one horizon they range up to 185 mm. in size. In all cases the ribbing is of normal perisphinctid biplicate style and, apart from slight coarsening towards the aperture and occasional development of polygyrate ribs, shows little modification. The aperture bears a horn-like process projecting from the venter. The umbilical seam gradually uncoils over the last half whorl, so that at the aperture many forms are completely evolute. The apertural margin is sometimes devoid of ribbing and shows a smooth zone, ornamented little, save for growth lines, and the presence of the ventral horn.

The macroconchs are usually 140–200 mm. in diameter, but occasionally are larger, or very rarely smaller, and are characterized by a smooth sinuous peristome margin. The ribbing on the inner whorls is of a simple biplicate style, but the point of bifurcation usually occurs slightly higher on the whorl side than it does on the microconchs. The body-chamber develops irregular ribbing and, particularly in the forms from higher horizons, has a tendency to fasciculation or virgatotomy. Uncoiling of the umbilical seam occurs only over the last half whorl.

The two forms are found in association throughout the succession, although the ratio of microconchs to macroconchs varies. This ratio is usually within the limits 2 : 1–1 : 2. Where only a few specimens have been obtained from one horizon this ratio is not treated as significant.

That these two groups of ammonites are very closely related is strongly suggested by their co-existence at each fossiliferous horizon, their identical stratigraphical range, and their similar rib curves. However, four specimens from one horizon (13 feet above the Rope Lake Head Stone Band) from which have been collected 32 microconchs and 34 macroconchs, show conclusively the relationship. Three of these specimens appear to be normal macroconchs, but have on their inner whorls structures resembling those of the horn of the microconch. However, this structure differs from the true microconch horn; it has negligible ventral projection, it is developed from a single rib, and it projects laterally.

The fourth of these specimens is unique in that it is intermediate in size between the two groups (117 mm. diameter), has the typical microconch horn developed, but shows the beginnings of the macroconch type of ribbing associated with four further horns. The rib density of the first three of the ammonites shows them to have affinity with the macroconch group. The fourth specimen has a rib density intermediate between that of a microconch and a macroconch.

The undersides of the ammonites, as they lie in the rock, are quite often encrusted with oysters, although the upper surface is generally free of them. It would, therefore, seem that the oysters attached themselves to the ammonite conch after the death of the latter, otherwise the oysters would presumably be equally common on both surfaces. They apparently grew in the shelter provided by the umbilical space beneath the ammonite, and flourished there until continued sedimentation eventually killed them. Medcof (1955) has shown that modern oyster larvae prefer to settle on under-surfaces. In this case the ammonite shells would provide the only such surfaces available on the sea bed.

Judging by the size of these oysters, a considerable time must have elapsed before they were killed by the continued influx of sediment, so that we may reasonably conclude that sedimentation was not rapid. This is also supported by lithological evidence. The rocks are a fairly uniform argillaceous series—grey and black shales and clays with occasional cementstone bands—and, apart from lamination, are devoid of sedimentary structures.

Save for the very occasional juvenile forms and occasional gerontic forms, all the ammonites fall into one of the two size groups mentioned previously, and bearing in mind the evidence of slow deposition, it is likely that the ammonite faunas of the Upper Kimmeridge Clay in Dorset represent a death assemblage.

Taking into account the evidence of maturity of the ammonites, and the fact that they represent death assemblages, it would appear evident that the difference in size of the two groups is of a fundamental nature. It seems most unlikely that current sorting of the shells, or sudden extermination of whole populations occurred. The most obvious interpretation of this size distribution is that these ammonites exhibit dimorphism. Dimorphism of ammonite shells is probably an expression of some difference which was present in the soft parts also. The most obvious difference between dimorphs would appear to be a sexual one, and there is some evidence to suggest that the microconch and macroconch may represent the two sexes.

Examination of the microconchs yields several important facts relating to the horn. It is never developed until a diameter of at least 60 mm. (generally more) is attained. In other words, the horn is not developed until a certain stage of growth is reached. At various growth stages beyond this diameter further horns may be developed, but the presence of a former horn or horns is always detectable. Sometimes the earlier horn is retained, and in other cases the earlier horns appear to have been shed, and to have left behind a characteristic scar on the venter.

Apart from the four macroconch specimens mentioned earlier, none shows any trace on the earlier whorls of any type of horn or ventral scar.

In section, the microconch horn is U-shaped, opening forwards. This suggests that it housed some part of the soft parts of the animal, and, since the horn is confined to the microconch, it is reasonable to assume that its function may have been sexual. This would explain its confinement to the microconch, and its occurrence only in nearly full-grown specimens.

The four specimens showing characteristics of each group can then be explained as various degrees of intersexual specimens. Three of them are barely distinguishable from true macroconchs, but the fourth appears to be a true intersex.

As mentioned above, the macroconchs and microconchs differ somewhat in the density of their ribbing. At 15 mm. diameter (the smallest diameter at which it is practicable to count the ribs accurately) the macroconchs are nearly always finer ribbed than the corresponding microconchs. The comparative density of the ribbing of the two forms, at greater diameters, is seen to vary with the species concerned. Presumably, both microconch and macroconch reached maturity at the same age, so that the rate of growth of the macroconch must have been greater than that of the microconch. This would appear to explain these discrepancies, since growth rate in each species must, to perhaps a small and varying extent, have had an effect on the density of the ribbing.

Our knowledge of the soft parts of ammonites is almost entirely based on analogy with modern cephalopods, particularly *Nautilus*. In most living cephalopods the male of the species is smaller than the female. In *Nautilus*, however, the male is slightly broader-shelled than the female, the extra breadth of the shell being utilised to incorporate the male copulatory organs, the diameter of the two shells is approximately equal. It appears, therefore, that in any case of marked dimorphism in modern cephalopods the male is the smaller sex, and it therefore appears likely that in *Pectinatites* the microconch represents the male of the species. If this were so, the horn may have assisted in copulation. If the spadix (the copulatory organ of the

male cephalopods) were housed within the horn, by insertion of the horn within the venter of the female shell, fertilization of the ova would be more readily assured.

Dimorphism has been reported in other groups of ammonites by various authors (e.g. Callomon 1963, Makowski 1962, Westermann 1964). In many of the reported instances, the microconch aperture bears a pair of lappets developed laterally. Lappets are not present in any ammonites found hitherto from the Upper Kimmeridge Clay, while the horn of the Kimmeridgian microconchs is apparently unique to this group of ammonites. These horned Kimmeridgian forms are known outside Britain from Northern France and Greenland, and, as they appear to have evolved rapidly, promise much in precise correlations within this Upper Jurassic faunal province.

Interpretation of PECTINATITES

The genus *Pectinatites* was originally proposed for a few closely related species from the *Pectinatus* Zone of Oxfordshire. The *Pectinatus* Zone there is to be correlated with the rocks between the White Stone Band, and the base of the *Pavlovia rotunda* Zone in the Dorset succession.

As early as 1896 Hudleston (1896 : 322) had remarked on the similarity between *Ammonites pectinatus* and the pyritized ammonites which occur at the top of the Kimmeridge Oil Shale or Blackstone, about 150 ft. below the White Stone Band in the Kimmeridge section.

Buckman, in June 1925, assigned one species of these pyritized ammonites from the Blackstone to a new genus, *Pectiniformites* which he placed six hemerae earlier than his *Pectinatus* hemera, but Neaverson (Dec. 1925) did not accept Buckman's findings, and placed these Blackstone ammonites in the genus *Pectinatites*. Spath (1936 : 18) in turn placed them in his genus *Subplanites* proposed in 1925.

Herein, I place these ammonites in the genus *Pectinatites*, in which I recognize three subgenera: *Pectinatites* (sensu stricto); *Virgatosphinctoides*; and *Arkellites* subgen. nov.

Many generic attributions have been given to species of *Pectinatites* in the past. These generic names, for the most part, belong to quite distinct genera many of which do not occur in Britain, while others of them are either junior synonyms, or in some cases subgenera of *Pectinatites*. As much confusion, and many unreliable correlations have been made on the basis of misidentification of species of *Pectinatites* with other genera, there follows a discussion of these genera and their relationship, if any, to *Pectinatites*.

VIRGATITES Pavlow 1892

TYPE SPECIES. *Ammonites virgatus* von Buch 1832. (Subsequently designated Douvillé 1910.)

This genus was recorded from the horizon of the Kimmeridge oil-shale by Salfeld (1913), and a zone of *V. miatschkovenssis* introduced by him for the beds between the *Gravesia* zones and his zone of *Perisphinctes pallasianus* (= modern *Pectinatus* Zone). The genus is characterized by virgatotome ribbing on the inner whorls, sometimes

reverting to simple or bifurcate ribbing on the body-chamber. All the Dorset ammonites from this part of the Kimmeridge Clay have normal perisphinctid bifurcate ribs on their inner whorls, and it is only on the outer whorl that virgatome ribbing may develop. There is now no doubt that *Virgatites* is much younger in age than these Kimmeridge forms, and appears to be restricted to the Volgian faunal province of eastern Europe.

PSEUDOVIRGATITES Vetter 1905

TYPE SPECIES. *Ammonites scruposus* Oppel in Zittel 1868.

Laplugh, Kitchin & Pringle (1923 : 222) recorded the occurrence of the genus *Pseudovirgatites* from Dorset, and introduced a zone of *Pseudovirgatites* to include the horizon of the Blackstone in Dorset. This genus is often homeomorphic with the genus *Pectinatites*. The type species from the Lower Tithonian has similar rib-style on its outer whorl to that of some large species of *Pectinatites* (e.g. *P. (Virgatosphinctoides) pseudoscruposus* (Spath)). Other species of *Pseudovirgatites*, such as some of those recently figured by Donze & Enay (1961) and Michailov (1964), are remarkably homeomorphic with some species of *Pectinatites* (e.g. *P. (P.) inconsuetus* sp. nov. See p. 138, Pl. 30). The microconch of *Pseudovirgatites* does not, however, possess a ventral peristomal horn as does *Pectinatites*, and all records of *Pseudovirgatites* from Britain would appear to refer to homeomorphic forms of *Pectinatites*.

LITHACOCERAS Hyatt 1900

TYPE SPECIES. *Ammonites ulmensis* Oppel 1863.

The inner whorls of *Lithacoceras* generally bear fine bifurcate ribs which modify on the outer whorl of the macroconch to produce in the type-species widely-spaced blunt primary ribs, each giving rise to up to eight secondaries. Some species of the genus reach a very large size. There is often a considerable degree of homeomorphy between species of this genus and species of *Pectinatites*. Apart from peristomal differences, the microconchs of the two genera can be very similar, and the middle whorls of a macroconch of *Lithacoceras* sometimes very closely approach the ornament of the macroconch of *Pectinatites*. This homeomorphy has misled many workers in the past. In particular the species of *Pectinatites* from the Hen Cliff Shales have been identified in the past as *Lithacoceras*. (e.g. Arkell 1956 : 21).

PECTINATITES Buckman 1922

TYPE SPECIES. *Ammonites pectinatus* Phillips 1871.

The name *Pectinatites* is the most senior available name for the British Upper Kimmeridgian ammonites described herein. It is distinguished from all other genera which are to varying degrees homeomorphic with it, by its type of dimorphism. As these ammonites with horned microconchs form a closely related natural group, it is here proposed to include all such dimorphic forms in this genus.

WHEATLEYITES Buckman 1923

TYPE SPECIES. *Wheatleyites tricostulatus* Buckman 1923.

This genus is characterized by finely-ribbed inner whorls, which modify to produce an outer whorl with coarse widely-spaced primary ribs; the secondary ribs gradually fade on the body-chamber. Some forms of *Wheatleyites* are homeomorphic with species of the Tithonian genus *Pseudovirgatites*. *Wheatleyites* is here regarded as a junior synonym of *Pectinatites*, it being a name applied by Buckman to macroconchs of *Pectinatites* having this particular type of modification of the ribs on the outer whorls.

SUBPLANITES Spath 1925 (January)

TYPES SPECIES. *Virgatosphinctes reisi* Schneid 1914.

To this genus belong a complex of forms occurring in the Tithonian rocks of Europe. Characteristically their inner whorls bear fine bifurcate ribs, which are modified on the body-chamber in a fashion similar to that which obtains in many species of *Pectinatites*. It was for this reason that many of the British species of *Pectinatites* were long considered to be species of *Subplanites*. *Virgatosphinctoides* Neaveverson (here treated as a subgenus of *Pectinatites*), was considered a junior synonym of *Subplanites*. This undetected homeomorphy led to the establishment of a number of unreliable correlations between Britain and Southern Europe.

The microconchs of *Subplanites* bear lappets, and are for this reason easily distinguishable from the microconchs of *Pectinatites* when material with intact peristomes is available, but in the absence of specimens with peristomes it is virtually impossible to distinguish the two genera.

All the British forms appear to belong to *Pectinatites*, but in the case of such faunas as those from Russia, recently described by Michailov (1964), it is not possible to determine the genus of ammonites present owing to the incomplete nature of the material.

PECTINIFORMITES Buckman 1925 (June)

TYPE SPECIES (by monotypy). *Pectiniformites bivius* Buckman 1925.

The holotype which is in the Dorset County Museum, Dorchester, is a pyritic cast from the Blackstone. The pyrite of the outer whorl has in places reached an advanced state of decomposition, and the specimen is now of little value. There is also in this museum, however, a cast of the holotype made in 1925, which appears to correspond very closely in dimensions to the holotype, and which is a better specimen than the holotype in its present condition.

Buckman marked on his plate of the holotype (1925, pl. 568) the position of the last visible suture, which is just one whorl back from the supposed peristome. However, the type of preservation in the Blackstone (solid pyrite) generally destroys all trace of the septa, and in the author's opinion, the septum marked by Buckman was the last *visible*, but not the last occurring septum. This view is supported by the occurrence of better-preserved ammonites having affinities with this species

and with a short body-chamber. (E.g. *Pectinatites pectinatus* (Phillips) Buckman 1922, pl. 354B, which shows five-eighths of a whorl of body-chamber; and the length of the body-chamber estimated from differences in the degree of crushing of the Dorset material, which suggests a body-chamber length of between three and five-eighths of a whorl. No specimen of *Pectinatites* is known to the author with a body-chamber as much as one whorl in length).

The ammonites from the Blackstone are largely uncrushed, but there is another, more important, difference between the ammonites from this horizon and other horizons in the Dorset succession. In the Blackstone, ammonites of all growth stages are preserved, from very small nuclei to specimens over 150 mm. in diameter. This contrasts with other horizons where mature individuals make up by far the greater part of the ammonite fauna. Furthermore, no ammonites have been collected (or preserved?) in the Blackstone with intact peristomes. This means that it is not possible, in the case of the smaller specimens, to distinguish macroconchs from microconchs, and thus that the interpretation of *Pectiniformites* is open to doubt.

Further, the Blackstone has hitherto failed to yield macroconchs with well-preserved inner whorls, so that the holotype of *Pectiniformites bivius* cannot be compared to any known macroconch specimen. It is, therefore, not possible to determine to which subgenus of *Pectinatites* this species belongs. The rib density is such that affinity with *Arkillites* subgen. nov. is unlikely (approximately 55 ribs at 30 mm. diameter). It may possibly therefore be consubgeneric with *Virgatosphinctoides*, but there appears to be no over-riding reason why it should not equally be placed in *Pectinatites*, *sensu stricto*. This was also the view of Neaverson (1925 : 15) "Buckman has recently instituted a new genus *Pectiniformites* for ammonites of the *pectinatus*-type from this facies (the oil shales of Kimmeridge). There seems to be no justification for this, and *Pectiniformites* must be regarded as synonymous with *Pectinatites*".

Pectiniformites would thus become a junior synonym of *Pectinatites*, and is so treated here.

KERATINITES Buckman 1925 (October)

TYPE SPECIES. *Keratinites keratophorus* Buckman 1925.

This genus was introduced by Buckman for ammonites from the *Pectinatus* Zone having a peristome bearing a ventral horn. These forms are the microconchs of *Pectinatites*, and the name *Keratinites* is here regarded as a junior synonym of *Pectinatites*.

VIRGATOSPHINCTOIDES Neaverson 1925 (December) : 11

TYPE SPECIES. *Virgatosphinctoides wheatleyensis* Neaverson 1925.

This genus is characterized by finely ribbed inner whorls which are modified on the body-chamber of the macroconch, often producing polygyrate, polyploke, or virgatotome ribbing. The genus was regarded by Spath as synonymous with, or at the most subgenerically different from, his genus *Subplanites* proposed a few months earlier (see above). Systematic collections from Dorset have now established that

Virgatosphinctoides is dimorphic. The microconchs bear a ventral horn and are never seen to have lappets. *Virgatosphinctoides* is thus easily distinguished from *Subplanites* when material with intact peristomes is available. The presence of a horned peristome, however, shows that *Virgatosphinctoides* is closely related to *Pectinatites*. The microconchs of the two are sometimes indistinguishable, and only the characters of the macroconchs can usefully separate the two forms. For this reason *Virgatosphinctoides* is here treated as a subgenus of *Pectinatites*.

ALLOVIRGATITES Neaverson 1925 (December) : 29

TYPE SPECIES. *Allovirgatites woodwardi* Neaverson 1925.

Neaverson's basis for distinction between *Virgatosphinctoides* and *Allovirgatites* appears to have been based almost entirely on differences in the septal suture of species of the two genera. However, the rib-style and its development is very similar in these two forms, and there appears to be little justification for drawing distinction between them. Neaverson admitted similarity between the suture lines of these two genera in the young stages, and there would seem little doubt that differences between his described forms are no more than specific differences. *Allovirgatites* is therefore here regarded as a junior synonym of *Virgatosphinctoides*.

SUBDICHOTOMOCERAS Spath 1925 (January)

TYPE SPECIES. *Subdichotomoceras lamplughii* Spath 1925.

This genus is characterized by sharply biplicate ribbing throughout development, together with deep constrictions which are bordered by simple ribs. The aperture is without lappets. The holotype came from the Eudoxus Zone of Yorkshire, and the genus does not appear to be represented in higher Kimmeridgian deposits in Dorset.

SPHINCTOCERAS Neaverson 1925 (December)

TYPE SPECIES. *Sphinctoceras crassum* Neaverson 1925.

Two species of *Sphinctoceras* were described by Neaverson from the Wheatleyensis Zone of Oxfordshire. They are massive inflated forms with coarse strong biplicate ribs. There seems little doubt that *Sphinctoceras* is closely related to *Subdichotomoceras*, the former being almost certainly the macroconch of the latter. No specimens of *Sphinctoceras* have hitherto been found in Dorset, but the genus is mentioned here because the conservative "biplex" stock to which it belongs gave rise to the pavloids in the Pectinatus Zone. The sharp biplicate ribbing, the very high point of bifurcation of the ribs, and the absence of polygyrate ribs and any marked apertural modification make identification of these forms with more coarsely-ribbed species of *Pectinatites* unlikely.

The origins of PECTINATITES

The origins of *Pectinatites* are rather obscure, but there is one feature of the ribbing which must be considered of great value in deducing the origin of the genus. This

is the presence of the polygyrate, and more rarely the polyploke rib type (Geyer 1961, text-fig. 1). This type of ribbing, which is first found in some Upper Oxfordian ammonites, is the first new character in perisphinctid ornamentation to appear since the Bajocian, and it therefore appears very probable that all ammonites which have this rib style are related.

In the Lower Kimmeridgian genus *Ataxioceras*, the development of polygyrate ribbing reaches its extreme. *Ataxioceras* is also often ribbed in a most irregular fashion, a character which is evident in many species of *Pectinatites*. A further character of *Ataxioceras* is of importance too in tracing the origin of *Pectinatites*. This is the apertural modification of the microconch. Most microconchs of *Ataxioceras* appear to have well-developed lappets (e.g. Geyer 1961a, pl. 14, fig. 2), but there are specimens which appear to have a horn developed (e.g. Geyer 1961a, pl. 13, fig. 5). It thus appears that three of the most important characters of *Pectinatites* are also found in *Ataxioceras*.

There must also be taken into account the remarkable similarity of some species of *Pectinatites* to species of the Tithonian genera *Subplanites*, *Lithacoceras*, and *Pseudovirgatites*. There can be no doubt that there was a marine connection between Britain and the Swabia-Franconia area at least for a short while after the Lower Kimmeridgian, since the genus *Gravesia* is common to both areas. However, there are apparently no substantiated records of *Lithacoceras* or *Subplanites* from the Lower Kimmeridgian of Britain. (In this respect I cannot accept Arkell's report of *Lithacoceras* from the *Aulacostephanus* zones (1947 : 73); or that of Ziegler of *Subplanites rueppellianus* from the same beds (1962 : 13)). All reported instances of these genera must, in the absence of any figured evidence to the contrary, be interpreted as occurrences of hitherto undescribed perisphinctids which in the author's opinion do not belong either to *Subplanites* or *Lithacoceras*.

The difference between *Subplanites* and *Lithacoceras* on the one hand, and *Pectinatites sensu lato* on the other hand has not been recognized hitherto owing to the failure to take note of the different types of dimorphism in the two faunal provinces. As shown above, the microconchs of *Pectinatites* are horned, the macroconchs have a straight peristome and often a tendency towards virgatotome ribbing on the body-chamber.

Subplanites and *Lithacoceras* both have lappeted microconchs, so that microconchs with intact peristomes are easily distinguishable from microconchs of *Pectinatites*. However, several species of microconchs of *Subplanites* such as *S. reisi*, *S. schlosseri*, and *S. moernsheimensis* have polygyrate ribbing on their body-chamber, and are similar in adult size and rib-style to macroconchs of species of *Pectinatites*, but differ in that the former bear lappets whereas the latter do not. When material without intact peristomes is compared, therefore, the two forms are virtually indistinguishable. Similarly *Lithacoceras* can be confused with *Pectinatites* when peristomes are not intact. Thus, previous comparisons of the British Kimmeridgian fauna to the Tithonian fauna have been comparisons between Kimmeridgian macroconchs and Tithonian microconchs. The similarity of the two faunas therefore must be regarded as an example of penecontemporaneous homeomorphy.

However the similarity of the rib-style of the two faunas, in particular the presence

of polygyrate ribbing, strongly suggests that they were derived from the same stock. This presumably lay in some of the less specialized of the Lower Kimmeridgian ataxioceratids, or in such a genus as the Upper Oxfordian *Discosphinctes* which has some polygyrate ribs on the body-chamber.

This being the case it would seem that *Lithacoceras* should be classified together with *Subplanites* and *Pectinatites* in the same sub-family. Arkell (1957) placed *Lithacoceras* in the sub-family Ataxioceratinae (Buckman 1921) whilst *Subplanites* and *Pectinatites* were assigned by him to the sub-family Virgatosphinctinae (Spath 1923). Since these three genera are presumed to be derivatives of the ataxioceratid stock, and not themselves ataxioceratids, they perhaps should be all placed together in the sub-family Virgatosphinctinae.

Subgenus **ARKELLITES** nov.

TYPE SPECIES. *Pectinatites (Arkellites) hudlestoni* sp. nov.

DIAGNOSIS. Dimorphic. Microconchs fairly coarsely ribbed on inner whorls. Body-chamber generally more coarsely ribbed than inner whorls. Horn sometimes little more than an inflation of ventral part of peristome. Macroconchs with similarly ribbed inner whorls to those of microconchs. Outer whorl showing little or no variocostation, ribs little changed to the peristome. Some species showing strengthening of primary ribs with development of intercalatory secondary and unbranched primary ribs. Polygyrate ribs generally rare. Peristome simple. Constrictions if present shallow. Suture line unknown.

Upper Kimmeridgian, Elegans to Hudlestoni Zones, ? Lower Pectinatus Zone.

Pectinatites (Arkellites) primitivus sp. nov.

(Pl. 2, figs. 1, 2; Pl. 3)

DIAGNOSIS. Macroconchs 125–150 mm. in diameter, with following rib densities: at 15 mm. 30–32 ribs; at 20, 32–34; 25, 33–35; 30, 33–36; 35, 36–37; 40, 37–38; 45, 37–38; 50, 39; 55, 40; 60, 41; 65, 43. Ribs rectiradiate to prorsiradiate with wide angle of furcation. Outer whorl variable but typically with frequent unbranched primary ribs. Microconchs 80–105 mm. in diameter, with following rib densities: at 15 mm. 32 ribs; at 20, 32–36; 25, 33–37; 30, 34–38; 35, 35–38; 40, 36–40. Ribs rectiradiate or slightly prorsiradiate. Outer whorl variable with bifurcate ribs predominating, sometimes with polygyrate and simple ribs, and intercalatory secondaries. Peristome slightly inflated ventrally.

HOLOTYPE. Macroconch C.73392.

PARATYPE. Macroconch C.73393.

PARATYPES (ALLOTYPES). Microconchs C.73394, C.73395.

MATERIAL. Nine specimens (four macroconchs, five microconchs).

HORIZON. Holotype, paratype and allotype C.73394, from 25 ft. below the Yellow Ledge Stone Band. Allotype C.73395 from 55 ft. below this band.

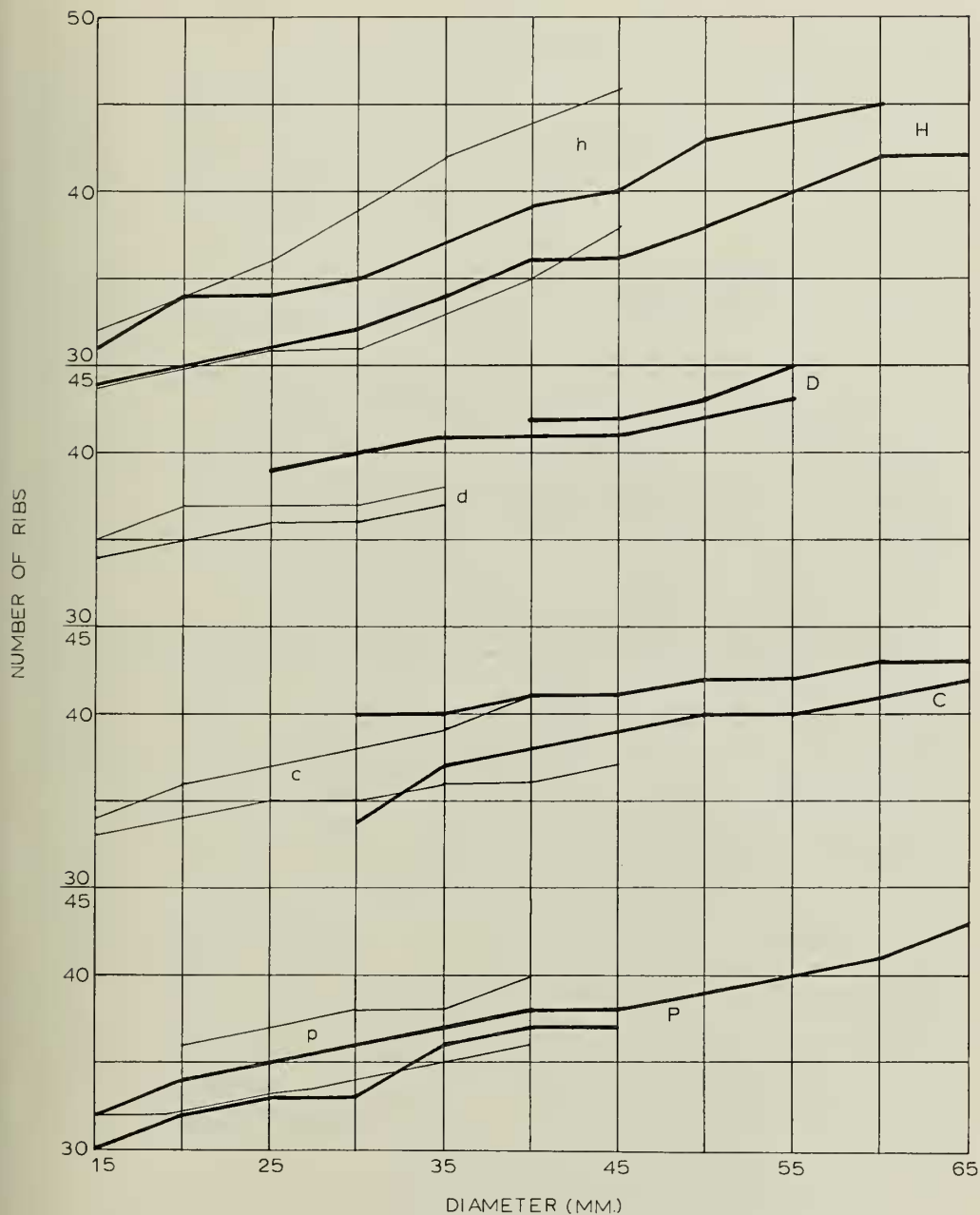


FIG. 3. Rib density of species of the subgenus *Arkellites*. Upper case letters : macroconchs ; lower case letters : microconchs. H, h : *P. (A.) hudlestoni* ; D, d : *P. (A.) damoni* ; C, c : *P. (A.) cuddlensis* ; P, p : *P. (A.) primitivus*.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Elegans Zone, between 12 and 55 ft. below the Yellow Ledge Stone Band (see below).

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 125-150 mm. Diameter of umbilicus 49-65 mm. The last whorl of the holotype has 54 primary and 76 secondary ribs, while the last whorl of the paratype has approximately 48 primary and 90 secondary ribs. At 20 mm. diameter there are 34 ribs; at 25, 35; 30, 36; 35, 36; 40, 37; 45, 37-38; 50, 39; 55, 40; 60, 41; 65, 43. The paratype has a similar rib-density.

The ribs on the inner whorls are rectiradial at the umbilical shoulder, then sweep forward to become prorsiradial. (The few apparently rursiradial ribs on the holotype have been distorted by crushing.) The point of bifurcation of the ribs is high on the whorl side. The umbilical seam gradually uncoils over the last half-whorl. The ribs on the outer whorl are either bifurcate or simple. The angle of bifurcation is larger than in most of the species of this subgenus. The holotype shows no fewer than 19 simple ribs on its outer whorl. The paratype has fewer simple ribs (approximately 9) and at least one trifurcate rib.

Microconch. Evolute shell with a diameter of between 80 and 105 mm. Diameter of umbilicus 32-40 mm. The last whorl of paratype C.73395 has approximately 45 primary and 103 secondary ribs. At 15 mm. diameter there are 32 ribs, at 20, 32-36; 25, 33-37; 30, 34-38; 35, 35-38; 40, 36-40.

The ribs on the inner whorl are rectiradial at the umbilical shoulder but curve forwards and become straight and slightly prorsiradial for the rest of their length. The point of bifurcation of the ribs is high on the whorl side. The umbilical seam uncoils over the last half whorl. The ribs on the outer whorl gradually become straight and rectiradial. There are three simple ribs on the last whorl of paratype C.73394, otherwise the ribs are bifurcate. The other paratype shows several polygyrate ribs on the last whorl. The peristome is slightly inflated ventrally.

REMARKS. The macroconch of this species shows features which are interpreted as being primitive characters of the genus. These include the wide angle of furcation of the ribs, the abundant unbranched primary ribs, and the relative absence of trifurcate (polygyrate) ribs. The microconchs exhibit only a feeble ventral inflation of the peristome. The outer whorl of allotype C.73395 shows resemblance in its rib-style to microconchs of species of the sub-genus *Virgatosphinctoides*, but the coarser ribbing of the inner whorls of the former provides easy distinction. It is possible, however, that the subgenus *Virgatosphinctoides* was derived from this species.

Incomplete and poorly preserved ammonites from the lowest Hen Cliff Shales, and their basal cementstone, may belong to this species. This would extend the range of the species down to 70 feet below the Yellow Ledge Stone Band.

Pectinatites (Arkellites) cuddlensis sp. nov.

(Pl. 4; Pl. 5, fig. 1)

DIAGNOSIS. Large stoutly-ribbed *Arkellites*. Macroconchs 160-210 mm. in diameter, with following rib densities: at 30 mm., 34-40 ribs; at 35, 37-40; 40, 38-41;

45, 39-41; 50, 40-42; 55, 40-42; 60, 41-43; 65, 42-43. Ribs rectiradiate to slightly prorsiradiate. Outer whorl with mainly bifurcate ribs, but some unbranched primary and occasional polygyrate ribs, and intercalatory secondary ribs. Microconchs 110-128 mm. in diameter, with following rib densities: at 15 mm., 33-34 ribs; at 20, 34-36; 25, 35-37; 30, 35-38; 35, 36-39; 40, 36-41; 45, 37. Ribs of inner whorls similar in style to macroconch. Peristome with ventral horn 6-21 mm. long.

HOLOTYPE. Macroconch C.73396.

PARATYPE (ALLOTYPE). Microconch C.73397.

MATERIAL. Nine specimens (five macroconchs, four microconchs).

HORIZON. Holotype from 18 ft. and paratype from 25 ft. above the Yellow Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, topmost *Elegans* to lower *Scitulus* Zones, 12 ft. below to 27 ft. above the Yellow Ledge Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 160-210 mm. The holotype has a diameter of 206 mm., and an umbilical diameter of 94 mm. There are 49 primary and 107 secondary ribs on the outer whorl of the holotype. At 30 mm. diameter the holotype has 34 ribs; at 35, 36; 40, 38; 45, 39; 50, 40; 55, 40; 60, 41; 65, 42; 70, 43; 75, 44; 80, 46; 85, 47; 90, 48. The variation in rib density within the species is shown in Text-fig. 3.

The ribs on the inner whorls are rursiradiate at the umbilical shoulder; they then swing forwards and become rectiradiate or slightly prorsiradiate and fairly straight. Some of the ribs on the inner whorls of the holotype are partially distorted by the crushing. The point of bifurcation of the ribs is high on the whorl-side. There is a slight uncoiling of the umbilical seam over the last half whorl.

The ribs on the outer whorl become stronger and their furcation somewhat irregular, with the development of intercalatory secondary ribs, unbranched primary ribs, occasional trifurcate ribs, and occasional furcation low in the whorl-side.

There do not appear to be any constrictions on the last whorl, although the rib style at one point (a trifurcate rib followed very closely by a simple rib) is very similar to that which obtains when a constriction is present.

The peristome is simple.

Microconch. Evolute shell with a diameter of 110-128 mm. Diameter of umbilicus 42-47 mm. The last whorl of the paratype has 43 primary and 89 secondary ribs. At 15 mm. diameter the paratype has 33 ribs; at 30, 34; 25, 36; 30, 38; 35, 39; 40, 41. The other microconchs of this species are similar to the paratype in rib density. (Text-fig. 3).

The ribs on the inner whorls are similar in style to those of the macroconch. The umbilical seam uncoils over the last half whorl, which appears to correspond to the length of the body-chamber. The ribs on the outer whorl coarsen slightly and are more or less straight and rectiradiate. There are occasional simple and trifurcate ribs on the last whorl.

The aperture bears a horn which is 21 mm. long on the paratype; the other complete microconchs have shorter horns.

REMARKS. This species has a similar, though not identical, density of ribbing on the inner whorls to that of *P. (A.) primitivus*, described above (p. 24). It differs, however, in adult size of both macroconch and microconch, and the density and style of ribbing of the outer whorl. It is probably, nevertheless, a derivative of this former species.

Pectinatites (Arkellites) damoni sp. nov.

(Pl. 5, figs. 2, 3; Pl. 6)

DIAGNOSIS. Macroconchs 136–160 mm. in diameter with following rib densities: at 25 mm. 39 ribs; at 30, 40; 35, 40–41; 40, 41–42; 45, 41–42; 50, 42–43; 55, 43–45. Ribs rectiradiate to slightly prorsiradiate. Outer whorl with irregular ribs with fairly wide angle of furcation, occasional unbranched primary ribs. No trifurcate ribs. Microconchs 70–90 mm. in diameter with following rib densities: at 15 mm. 34–35 ribs; at 20, 35–37; 25, 36–37; 30, 36–37; 35, 37–38. Ribs generally prorsiradiate. Outer whorl with occasional unbranched primary and polygyrate ribs. Peristome with ventral ribbed horn 3–15 mm. long.

HOLOTYPE. Macroconch C.73398.

PARATYPE. Macroconch C.73399.

PARATYPES (ALLOTYPES). Microconchs C.73400, C.73401.

MATERIAL. Sixteen specimens (four macroconchs, twelve microconchs).

HORIZON. Holotype and allotypes from 25 ft., paratype from 27 ft. above the Yellow Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, lower Scitulus Zone, ranging between 15 and 32 ft. above the Yellow Ledge Stone Band.

DESCRIPTION. *Macroconch*. Moderately evolute shell with a diameter of 130–160 mm. Diameter of umbilicus 54–60 mm. The holotype has approximately 41 primary ribs on the last whorl. No macroconch of this species with a complete last whorl has been found. At 25 mm. diameter the holotype has 39 ribs; at 30, 40; 35, 40; 40, 41; 45, 41; 50, 42; 55, 43; 60, 43. The variation in rib density within the species is shown in Text-fig. 3.

On the inner whorls the ribs are rursiradiate at the umbilical shoulder, they then swing forwards to become rectiradiate or slightly prorsiradiate and more or less straight. The point of bifurcation of the ribs is high on the whorl-side, and is not always visible on the innermost whorls. There is a slight uncoiling of the umbilical seam over the last half to three-quarters of a whorl.

The ribs on the outer whorl are rather "untidy" in appearance. They become coarser and have quite a wide angle of furcation. Occasional simple ribs are developed, but there is an absence of trifurcate ribs. No constrictions are visible.

Although no specimen has its peristome preserved intact, it is presumably simple.

Microconch. Evolute shell having a diameter of 70–90 mm. Diameter of umbilicus 25–35 mm. The last whorl of paratype C.73400 has 42 primary and 86 secondary ribs. The density of the ribs on the inner whorls can only be approxi-

mately determined on this specimen. Paratype C.73401 has 35 ribs at both 25 and 30 mm. diameter. Other microconchs of the species show similar rib densities (Text-fig. 3).

The ribs of the inner whorls are similar in style to those of the macroconch, but tend to be more prorsiradiate. On the outer whorl the forward inclination is not so pronounced, and the ribs approach the rectiradiate condition. The point of bifurcation of the ribs is quite high on the whorl-side, and is not always visible on the inner whorls. The umbilical seam uncoils gradually over the last half whorl. The length of the body-chamber (estimated by differences in the degree of crushing) is usually half a whorl long, but in some specimens it appears to be only about three-eighths of a whorl in length.

The ribs on the outer whorl are slightly coarser than those of the inner whorls. There may be several simple and occasional trifurcate ribs on the last whorl. The ventral part of the peristome bears a horn which varies in length from 3-15 mm. and is always quite strongly ribbed.

REMARKS. The macroconch of this species shows some similarity with that of *P. (A.) primitivus*, described above (p. 24). It differs in the density of ribbing of the inner whorls. The respective microconchs are not likely to be confused on account of size, rib style and density, and horn development. This species may, however, be derived from *P. (A.) primitivus*. Adult size of both macroconch and microconch, and the very irregular ribbing of the outer whorl distinguished *P. (A.) damoni* from *P. (A.) cuddlensis*.

Pectinatites (Arkellites) huddlestoni sp. nov.

(Pl. 2, fig. 3; Pl. 7; Pl. 8, fig. 2)

DIAGNOSIS. Large *Arkellites* with stout blunt ribs. Macroconchs 170-196 mm. in diameter with following rib densities: at 15 mm. there are 29-31 ribs; at 20, 30-34; 25, 31-34; 30, 32-35; 35, 34-37; 40, 36-39; 45, 36-40; 50, 38-43; 55, 40-44; 60, 42-45. Ribs rectiradiate to slightly rursiradiate. Ribs on outer whorl becoming blunt and massive, with abundant intercalatory secondary ribs and occasional unbranched primary ribs. Microconchs 72-112 mm. in diameter, with following rib densities: at 15 mm., 29-32 ribs; at 20, 30-34; 25, 31-36; 30, 31-39; 35, 33-42; 40, 35-44; 45, 38-46. Ribs approximately rectiradiate, branching fairly low on whorl-side. Ribs coarser on outer whorl with occasional simple and rare polygyrate ribs. Peristome with well-developed ventral horn 4-21 mm. long. Horn ornamented only by growth lines.

HOLOTYPE. Macroconch C.73403.

PARATYPE (ALLOTYPE). Microconch C.73404.

MATERIAL. Twenty-four specimens, including eleven plaster casts. Five macroconchs, nineteen microconchs.

HORIZON. Holotype and paratype from shales 13 ft. above the Rope Lake Head Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Hudlestoni Zone, from 12 ft. above the Rope Lake Head Stone Band to 9 ft. below the White Stone Band.

DESCRIPTION. *Macroconch*. The dimensions given below are from the holotype which is the only reasonably complete macroconch which is well-preserved.

Stoutly ribbed evolute shell with a diameter of 196 mm. Diameter of the umbilicus 93 mm. There are 42 primary and 96 secondary ribs on the last whorl. At 15 mm. diameter there are 31 ribs; at 20, 32; 25, 32; 30, 33; 35, 34; 40, 36; 45, 36; 50, 38; 55, 40; 60, 42; 65, 42; 70, 43; 75, 44; 80, 45; 85, 46; 90, 46. The variation in rib density is shown in Text-fig. 3.

The ribs on the inner whorls have a slight rursiradial curve at the umbilical shoulder; for the rest of their length they are straight and rectiradial, or slightly rursiradial. The point of bifurcation is high on the whorl-side apart from occasional ribs which branch near the umbilical shoulder. The umbilical seam uncoils over the last five-eighths of a whorl.

On the outer whorl the ribs gradually become blunt and massive. The primary ribs branch to give only two secondary ribs; no trifurcate ribs are developed. There are, however, abundant intercalatory secondary ribs, and one or two simple ribs.

The peristome is not preserved completely, but in the absence of any contrary evidence, is assumed to be simple.

Microconch. Evolute shell with a diameter of 72-112 mm. Diameter of the umbilicus 26-45 mm. The paratype has a diameter of 98 mm. and an umbilical diameter of 44 mm. It has 55 primary and 110 secondary ribs on its outer whorl. At 15 mm. diameter the paratype has 31 ribs, at 20, 33; 25, 35; 30, 36; 35, 39; 40, 40; 45, 42. The variation in rib density is shown in Text-fig. 3.

The ribs on the inner whorls are of similar style to those of the macroconch, but the point of bifurcation is somewhat lower on the whorl-side. The umbilical seam uncoils over the last half whorl.

The ribs on the last whorl gradually become coarser; occasional simple ribs are developed, and very rarely a trifurcate rib.

The peristome is straight and has a well developed ventral horn. On the paratype the horn projects 20 mm. from the venter, but it may be as short as 4 mm. The horn itself is ornamented only by growth lines, the ribs on the whorl-side fading as they approach the venter in the vicinity of the horn.

REMARKS. This species is younger in age than other species of this subgenus recorded hitherto. It is distinguished by its rib-style, particularly the tendency for the ribs of the macroconch to be slightly rursiradial. The microconch horn also tends to be free of ornamentation. On some specimens (e.g. C.73402 figured in Pl. 2, fig. 3) the venter bears scars, suggesting that earlier formed horns may have been shed.

Subgenus *VIRGATOSPHINCTOIDES* Neaverson 1925 : 11

1925 *Allovirgatites* Neaverson : 29.

TYPE SPECIES. *Virgatosphinctoides wheatleyensis* Neaverson 1925.

DIAGNOSIS. Dimorphic. Macroconchs generally finely ribbed on inner whorls. Outer whorl very variable; primary ribs strong and typically with frequent polygyrate furcation, and often a tendency to become fasciculate or virgatotome; secondary ribs obsolescent in some large species. Variocostation slight to pronounced. Peristome simple. Microconchs similarly ribbed on inner whorls to macroconchs. Body-chamber usually more coarsely ribbed than inner whorls. Peristome typically with well-developed ventral horn, more rarely only with ventrally inflated peristome. Constrictions commonly present, particularly in macroconchs.

Upper Kimmeridgian, *Elegans* to *Hudlestoni* Zones.

Pectinatites (Virgatosphinctoides) elegans sp. nov.

(Pl. 8, figs. 1a, 1b; Pl. 9)

DIAGNOSIS. Macroconchs 154-184 mm. in diameter with following rib densities: at 15 mm. diameter there are approximately 37 ribs; at 20, 38; 25, 39; 30, 39-42; 35, 40-43; 40, 41-45; 45, 42-46; 50, 43-47; 55, 44-48; 60, 45-49; 65, 46-50. Ribs slightly prorsiradiate, fairly straight. Outer whorl developing strengthened primary ribs, mainly bifurcate, but with occasional simple and polygyrate ribs and intercalatory secondaries. Microconchs 100-112 mm. in diameter with following rib densities: at 20 mm. diameter there are 39-44 ribs; at 25, 40-45; 30, 41-45; 35, 42-46; 40, 44-47. Ribs of inner whorls similar to macroconch, outer whorl slightly more strongly ribbed with occasional simple and polygyrate ribs. Peristome with ventral inflation projecting 4-8 mm.

HOLOTYPE. Macroconch C.73405.

PARATYPE (ALLOTYPE). Microconch C.73406.

MATERIAL. Fifteen specimens (six macroconchs, nine microconchs).

HORIZON. Holotype from 18 ft. and paratype from 20 ft. below the Yellow Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, *Elegans* Zone, between 50 and 16 ft. below the Yellow Ledge Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 154-184 mm. Diameter of the umbilicus 65-76 mm. There are 61 primary and 137 secondary ribs on the last whorl of the holotype. At 40 mm. diameter the holotype has 45 ribs, at 45, 66; 50, 47; 55, 48; 60, 48; 65, 49; 70, 50. The variation in rib density is shown in Text-fig. 4.

The sharp dense ribs on the inner whorls are slightly prorsiradiate and straight for most of their length, but at the umbilical shoulder are rectiradiate or rursiradiate as with other species of this subgenus. The point of bifurcation of the ribs is very high on the whorl side. The umbilical seam uncoils over the last half-whorl.

The ribs on the outer whorl are similar in style to those of the inner whorls but gradually become more blunt and more widely spaced. Occasional simple and polygyrate ribs are developed on the outer whorl, but bifurcate ribs predominate.

The peristome is simple.

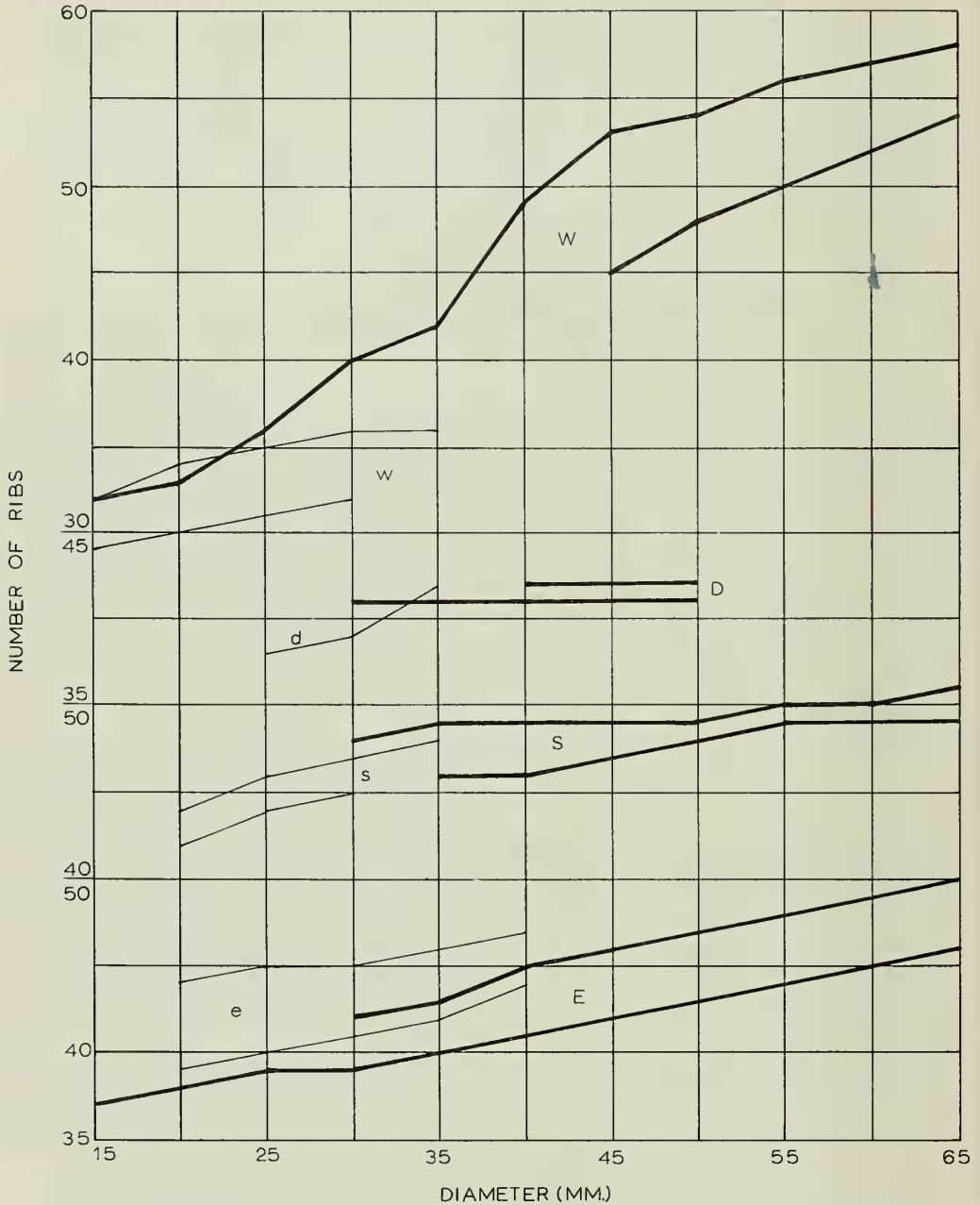


FIG. 4. Rib density of species of the subgenus *Virgatosphinctoides*. Upper case letters : macroconchs ; lower case letters : microconchs. W, w : *P. (V.) woodwardi* ; D, d : *P. (V.) decorosus* ; S, s : *P. (V.) scitulus* ; E, e : *P. (V.) elegans*.

Microconch. Evolute shell with a diameter of 100–112 mm. Diameter of the umbilicus (paratype) 40 mm. The paratype has 66 primary and approximately 130 secondary ribs on the last whorl. At 15 mm. diameter the paratype has approximately 42 ribs; at 20, 44; 25, 45; 30, 45; 35, 46; 40, 47. The variation in rib density is shown in Text-fig. 4.

The rib style of the inner whorls is very similar to that of the macroconch. The umbilical seam uncoils over the last half whorl. No suture is visible, but differences in the degree of crushing suggest that the body-chamber is half a whorl in length. The ribs on the last half whorl become slightly coarser, and occasional simple and trifurcate ribs are developed. The peristome curves forward ventrally and is inflated on the ventral margin which projects 8 mm. on the paratype. The ribs pass uninterrupted over the projection.

REMARKS. This is the earliest known species of the subgenus *Virgatosphinctoides*. The origin of the subgenus may have been from *P. (Arkelites) primitivus* described above (p. 24), the microconch of which shows a broadly similar rib style to this species. It is readily distinguished, however, by the much more finely ribbed inner whorls and the pronounced peristomal inflation. *P. (V.) elegans* is distinguished from later species of the subgenus by its rib-density, the peristomal development of the microconch and the body-chamber ornament of the macroconch.

Pectinatites (Virgatosphinctoides) elegans corniger subsp. nov.

(Pl. 10)

DIAGNOSIS. Macroconch approximately 125 mm. in diameter with following approximate rib densities: at 30 mm. 48 ribs; at 35, 49; 40, 50; 45, 51; 50, 52. Ribs prorsiradiate, fairly straight. Outer whorl developing strengthened primary ribs with fairly frequent polygyrate ribs. Microconch 82–85 mm. in diameter with following rib densities: at 20 mm. diameter approximately 43 ribs; at 25, 45; 30, 46. Inner whorls similarly ribbed to macroconch, outer whorl slightly more coarsely ribbed with occasional simple and polygyrate ribs. Peristome with ventral horn up to 7 mm. long.

HOLOTYPE. Macroconch, C.73407.

PARATYPES (ALLOTYPES). Microconchs. C.73408, C.73409.

MATERIAL. The holotype and two paratypes.

HORIZON. Holotype and paratype C.73408 from 5 ft., and paratype C.73409 from 8 ft. below the Yellow Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, topmost *Elegans* Zone, between 5 and 8 ft. below the Yellow Ledge Stone Band (see below).

DESCRIPTION. *Macroconch.* Evolute shell with an estimated diameter of 123 mm. Diameter of the umbilicus 50 mm. The last whorl has approximately 53 primary ribs. The number of secondary ribs cannot be determined since a part of the outer whorl has been broken away. At 39 mm. diameter there are 48 ribs; at 35, 49; 40, 50; 45, 51; 50, 52.

The ribs on the inner whorls are of a similar style to those of *P. (A.) elegans* described above but tend to be a little more prorsiradiate. The point of bifurcation of the ribs is high on the whorl side. The umbilical seam uncoils over the last half whorl. The last umbilical whorl shows the development of occasional trifurcate and simple ribs; these become more numerous on the outer whorl, where there is some degree of variocostation. Over the last half whorl the primary ribs become more widely spaced and more pronounced, and there are frequent polygyrate ribs.

The peristome is not completely preserved, but is presumably simple.

Microconch. Evolute shell with a diameter of 82–85 mm. Diameter of the umbilicus 28–32 mm. There are 55–63 primary and 122–130 secondary ribs on the last whorl. At 20 mm. diameter there are 43 ribs; at 25, 45; 30, 46.

The rib style of the inner whorls is similar to that of the macroconch. The umbilical seam uncoils over the last half whorl, which appears to correspond to the length of the body-chamber, to judge by differences in the degree of crushing.

The ribs on the outer whorl are of similar style to those of the inner whorls, but become slightly coarser with the tendency to develop occasional polygyrate and simple ribs. The peristome is curved forwards dorsally, and ventrally has a horn which is 7 mm. long on paratype C.73408. The secondary ribs pass uninterrupted over the horn.

REMARKS. One fragment of an ammonite possibly belong to this subspecies was collected from the Yellow Ledge Stone Band, thus the stratigraphical range of the subspecies may extend upwards to the top of the *Elegans* Zone.

The subspecies is intermediate in many respects between *P. (V.) elegans* (p. 31) and *P. (V.) scitulus* (p. 34). It is intermediate in age between the two, and shows characters of both species. It is distinguished from the former species by the smaller adult size of both its macroconch and microconch, the peristomal development of the microconch, and the more strongly ribbed body chamber of the macroconch. Distinction from the latter species is based on the adult size of the macroconch and microconch, the peristomal development of the microconch, and the ribbing on the body-chamber of the macroconch which is not so markedly variocostate as in *P. (V.) scitulus*. The rib-density of the subspecies shows a closer relationship to *P. (V.) scitulus* than to *P. (V.) elegans*; however, the subspecies is assigned to the latter species because the ornament of the body-chamber of the macroconch, and the ribbed horn of the microconch show more affinity to the developments of these characters in *P. (V.) elegans*. This subspecies appears to form a direct phylogenetic link between *P. (V.) elegans* and *P. (V.) scitulus*.

***Pectinatites (Virgatosphinctoides) scitulus* sp. nov.**

(Pl. 11)

DIAGNOSIS. Macroconchs 130–162 mm. in diameter with following rib densities: at 30 mm. diameter approximately 48 ribs; at 35, 46–49; 40, 46–49; 45, 47–49; 50, 48–49; 55, 49–50; 60, 49–50; 65, 49–51. Ribs rectiradiate to slightly prorsiradiate, straight. Outer whorl with strengthened primary ribs and variable number of

simple and polygyrate ribs with occasional intercalatory secondary ribs. Microconchs 67–82 mm. in diameter with following rib densities: at 20 mm. diameter 42–44 ribs; at 25, 44–46; 30, 45–47; 35, 48. Inner whorls similar to macroconch. Outer whorl with slightly stronger ribs with tendency to be flexuous, and with occasional simple and polygyrate ribs. Peristome with feebly-ribbed ventral horn 7–16 mm. long.

HOLOTYPE. Macroconch C.734I1.

PARATYPE (ALLOTYPES). Microconchs C.734I2, C.734I3.

MATERIAL. Twenty-two specimens (ten macroconchs, twelve microconchs).

HORIZON. Holotype from 24 ft. above the Yellow Ledge Stone Band. Paratypes from 25 and 15 ft. respectively above this band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, lower half of Scitulus Zone, occurring in the Yellow Ledge Stone Band and up to 44 ft. above this horizon.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 130–162 mm. The holotype is 162 mm. diameter. Diameter of the umbilicus 50–78 mm. There are 47 primary and 99 secondary ribs on the last whorl of the holotype, other specimens have similar rib density on the last whorl. At 30 mm. diameter the holotype has 48 ribs; at 35, 49; 40, 49; 45, 49; 50, 49; 55, 50; 60, 50; 65, 51; 70, 52; 75, 52. The variation in the rib density is shown in Text-fig. 4.

The ribs on the inner whorls are dense and sharp. At the umbilical shoulder there is a slight rursiradial curve; the ribs then swing forwards and become straight and rectiradial or slightly prorsiradial. The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils over the last half whorl.

The outer whorl develops coarser ribs; the primary ribs become more widely spaced, and there is the development of simple and polygyrate ribs, and intercalatory secondary ribs. There appear to be several constrictions of the shell over the last whorl, but the crushing does not allow this to be definitely ascertained. There is considerable variability in the sculpture of the outer whorl, some specimens having very frequent polygyrate ribs. The peristome is simple. The length of the body-chamber is unknown.

Microconch. Evolute shell with a diameter of 67–82 mm. Diameter of the umbilicus 25–32 mm. Paratype C.734I3 has 45 primary and 92 secondary ribs on the last whorl; other specimens have similar rib density on the last whorl. At 20 mm. diameter there are 42 ribs; at 25, 44; 30, 45. Variation in rib density of the inner whorls is shown in Text-fig. 4.

The ribs on the inner whorls are identical in style to those of the macroconch. The umbilical seam uncoils over the last half whorl. Differential crushing suggest that the body-chamber varies in length from half to five-eighths of a whorl.

The outer whorl has somewhat coarser ribs which tend to be a little flexuous. At the umbilical shoulder they are rursiradial, then swing forwards to become slightly prorsiradial, rectiradial, or slightly rursiradial. There are occasional simple and polygyrate ribs on the last whorl, which may have a few constrictions.

The peristome has a ventral horn which varies in length from 7 to 16 mm. The horn is only feebly ribbed.

REMARKS. The points of distinction between this species and *P. (V.) elegans* and *P. (V.) elegans corniger* have been discussed above (p. 34). It is readily distinguished from *P. (V.) decorosus* described below (p. 36) by the rib density of the inner whorls.

Pectinatites (Virgatosphinctoides) decorosus sp. nov.

(Pl. 12)

DIAGNOSIS. Macroconchs 120–140 mm. in diameter with following rib densities: at 30 mm. diameter there are 41 ribs; at 35, 41; 40, 41–42; 45, 41–42; 50, 41–42. Ribs of inner whorls fairly straight and prorsiradiate; outer whorl developing coarser more widely spaced rectiradiate ribs, with occasional constrictions followed by simple unbranched primary rib. Microconchs approximately 85 mm. in diameter with following approximate rib densities: at 25 mm. diameter there are 38 ribs; at 30, 39; 35, 42. Inner whorls ribbed similarly to macroconch, outer whorl with stronger rectiradiate ribs, occasionally simple or polygyrate. Peristome with ventral horn up to 9 mm. long.

HOLOTYPE. Macroconch C.73414.

PARATYPE (ALLOTYPE). C.73415.

MATERIAL. Eight specimens (four macroconchs, four microconchs).

HORIZON. Holotype and paratype from 15 ft. above the Yellow Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Scitulus Zone, 15 to 30 ft. above the Yellow Ledge Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 120–140 mm. Diameter of the umbilicus 54–66 mm. The last whorl of the holotype has 43 primary and approximately 96 secondary ribs. At 30 mm. diameter there are 41 ribs; at 35, 41; 40, 41–42; 45, 41–42; 50, 41–42.

The ribs on the innermost whorls are very slender and delicate; they are fairly straight and slightly prorsiradiate. An initial rursiradial curve then develops at the umbilical shoulder; the ribs then swing forwards to become prorsiradiate. The point of bifurcation of the ribs is quite high on the whorl side. The umbilical seam uncoils over the last half whorl.

The ribs on the outer whorl gradually become coarser and more widely spaced, and lose most of their initial rursiradial curve to become fairly straight throughout their length. They are mainly rectiradiate, but vary from slightly rursiradiate to slightly prorsiradiate. There appear to be four or five constrictions on the outer whorl of the holotype. These are usually preceded by a polyploke rib, formed by the fusion close to the umbilical shoulder of two bifurcate ribs, and are always followed by a simple rib. Apart from these modifications, and the occasional intercalatory rib, all the ribs are bifurcate.

The peristome is simple.

Microconch. Evolute shell with a diameter of approximately 85 mm. All the measurements given are from the paratype which is the only well-preserved microconch. Diameter of the umbilicus 35 mm. The last whorl has 46 primary and approximately 90 secondary ribs. At 25 mm. diameter there are 38 ribs; at 30, 39; 35, 42.

The rib style on the inner whorls is similar to that of the macroconch. The umbilical seam uncoils over the last half whorl (which is estimated to be the length of the body-chamber). The ribs on the outer whorl are strong and rectiradiate; they are mainly bifurcate, but there are occasional simple and polygyrate ribs.

The peristome has a ventral horn of moderate length (9 mm. on the paratype) and which is ribbed. It arises gradually as an extension of the venter, and does not project very sharply as is the case in several other species of the genus.

REMARKS. The density and style of ribbing of this species render it readily distinguishable from allied species such as *P. (V.) scitulus* described above (p. 34). The rib density of the inner whorls shows some similarity to that of *P. (A.) cuddlensis* described above (p. 26), but adult size, rib style, and rib density of the outer whorl differ markedly in the two forms.

Pectinatites (Virgatosphinctoides) major sp. nov.

(Pl. 13)

DIAGNOSIS. Very large *Virgatosphinctoides* with little varicocostation. Diameter approximately 240–320 mm., with following rib densities: at 50 mm. diameter there are 42–47 ribs; at 60, 44–48; 70, 46–50; 80, 48–51; 90, 49–53; 100, 50–55; 110, 51–55; 120, 52–56; 130, 54–56; 140, 57. Ribs of inner whorls slender, rectiradiate to prorsiradiate; outer whorl with stronger rectiradiate ribs, with some simple and polygyrate ribs.

HOLOTYPE. Macroconch C.73410.

MATERIAL. Ten specimens (all macroconchs).

HORIZON. Holotype from 6 ft. below the Yellow Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Upper part of Elegans Zone and Scitulus Zone, 20 ft. below the Yellow Ledge Stone Band up to the Cattle Ledge Stone Band.

DESCRIPTION. *Macroconch.* Evolute shell with a diameter of 240–320 mm. The diameter of the umbilicus varies from 130–150 mm. The holotype is 318 mm. in diameter, has an umbilical diameter of 140 mm., and 59 primary and 124 secondary ribs on the last whorl. At 50 mm. diameter it has 46 ribs; at 55, 47; 60, 48; 65, 49; 70, 50; 75, 50; 80, 51; 85, 52; 90, 53; 95, 54; 100, 55; 105, 55; 110, 55; 115, 55; 120, 56; 125, 65; 130, 56; 135, 57; 140, 57.

The ribs on the inner whorls are slightly rursiradiate at the umbilical shoulder, and then bend forwards and become either rectiradiate or slightly prorsiradiate. The point of bifurcation of the ribs occurs fairly high on the whorl-side. The umbilical seam uncoils over the last half whorl. The length of the body-chamber is

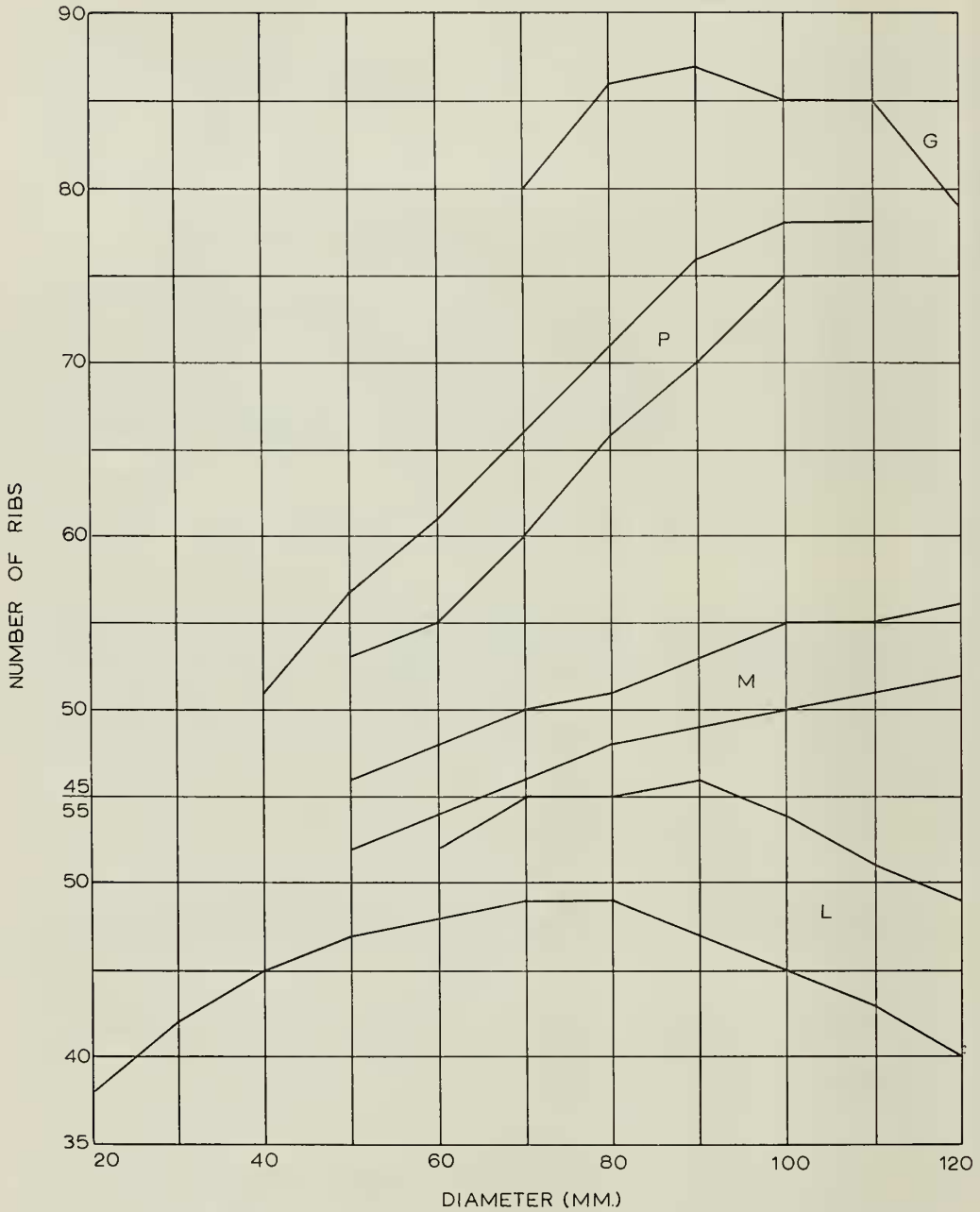


FIG. 5. Rib density of species of the subgenus *Virgatosphinctoides*. G: *P. (V.) grandis*; P: *P. (V.) pseudoscruposus*; M: *P. (V.) major*; L: *P. (V.) laticostatus*.

unknown, but would appear to be greater than two-thirds of a whorl, if the differential crushing is a reliable guide. The ribs on the outer whorl gradually lose their initial rursiradial curve, and become rectiradial throughout. There is little variocostation in this species, and the ribs of the outer whorl remain predominantly bifurcate. There are, however, occasional simple and more rarely polygyrate ribs. The holotype shows, in addition, one rib near the smooth peristome margin, which bifurcates very low on the whorl-side and again higher on the whorl, producing a total of four secondary ribs. This type of furcation (polyploke) is not seen on any other specimen of the species, otherwise the other specimens show little variation from the holotype, except that some of the specimens from higher horizons tend to develop a slightly lower point of furcation of the ribs on the body-chamber.

The microconch of this species is unknown.

REMARKS. The very large size of this species renders it readily distinguishable from other species of *Pectinatites* of the same age. It may be distinguished from other large species of the genus (all of which, described hitherto, are of younger age) by the very small degree of variocostation.

Pectinatites (Virgatosphinctoides) clavelli sp. nov.

(Pl. 14)

DIAGNOSIS. Macroconchs 210–260 mm. in diameter with following approximate rib densities: at 40 mm. diameter there are 46 ribs; at 50, 49; 60, 54–57; 70, 55–61; 80, 56–66. Ribs of inner whorls slender and rectiradial. Outer whorl developing widely-spaced massive blunt primary ribs with frequent polygyrate furcation, and intercalatory secondary ribs. Microconchs 67–87 mm. diameter with following rib densities: at 25 mm. diameter there are 42 ribs; at 30, 43–44; 35, 44. Inner whorls similarly ribbed to macroconch. Outer whorls somewhat more coarsely-ribbed with occasional polygyrate and simple ribs. Peristome projecting ventrally by up to 5 mm.

HOLOTYPE. Macroconch C.73432.

PARATYPES (ALLOTYPES). Two microconchs, C.73433, C.73434.

MATERIAL. Eleven specimens, all plaster casts (five macroconchs, six microconchs).

HORIZON. Holotype from 8 ft., and paratypes from 3 ft. above the Grey Ledge Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, lower Wheatleyensis Zone, between 3 and 28 ft. above the Grey Ledge Stone Band.

DESCRIPTION. *Macroconch*. Large evolute shell with a diameter of approximately 210–260 mm. The diameter of the umbilicus varies from 104 to 130 mm.

The last whorl of the holotype which is 212 mm. in diameter has 51 primary and an estimated 122 secondary ribs. The innermost whorls are not completely preserved in any one specimen. At 60 mm. diameter the holotype has 57 ribs, at 70, 62; 80, 66; 90, 69; 100, 71. The variation in rib density is shown in Text-fig. 6.

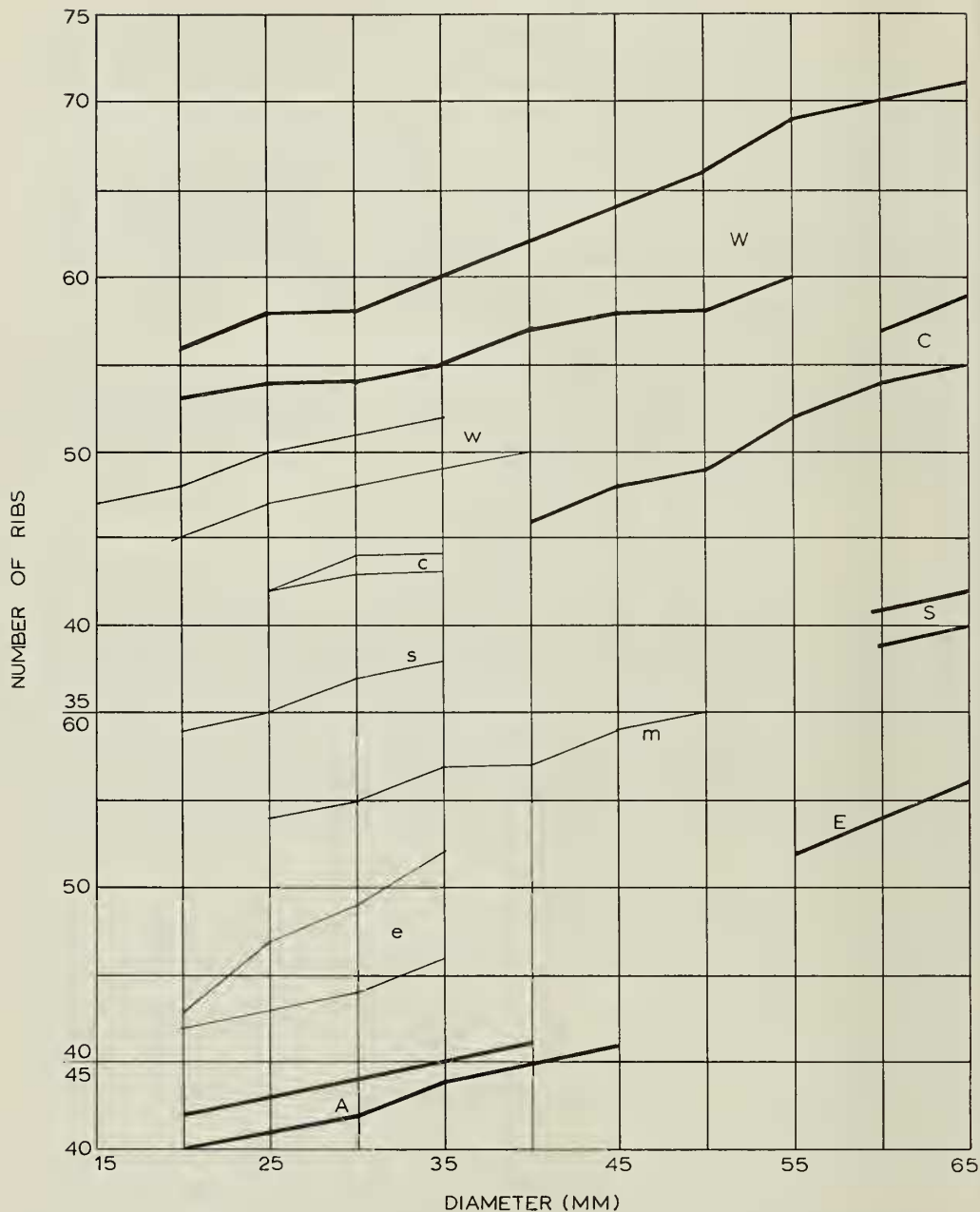


FIG. 6. Rib density of species of the subgenus *Virgatosphinctoides*. Upper case letters : macroconchs ; lower case letters : microconchs. W, w : *P. (V.) wheatleyensis* ; C, c : *P. (V.) clavelli* ; S, s : *P. (V.) smedmorensis* ; m : *P. (V.) magnimasculus* ; E, e : *P. (V.) encombensis* ; A : *P. (V.) abbreviatus*.

The ribs on the inner whorl are rursiradiate at the umbilical shoulder; they then swing forwards and become straight and more or less rectiradiate. The point of bifurcation of the ribs is high on the whorl-side. There is a marked uncoiling of the umbilical seam over the last half whorl.

The ribs on the outer whorl become coarser, and the primary ribs become more widely spaced and irregular in their style and furcation. Some are rursiradiate, others rectiradiate or prorsiradiate. Several of the primary ribs show polygyrate furcation, and there is also a profusion of simple and intercalatory ribs on the last whorl.

The peristome is simple.

Microconch. Evolute shell considerably smaller than the macroconch, having a diameter of only 68–87 mm. The diameter of the umbilicus is 30–37 mm. There are 46 primary and 94 secondary ribs on the last whorl of paratype C.73434. The rib style of the inner whorls is similar to that of the macroconch. At 25 mm. diameter there are 42 ribs; at 30, 43–44; at 35, 44. (Text-fig. 6).

The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils noticeably over the last half whorl.

The outer whorls of both specimens are rather distorted by the crushing so that it is not easy to determine the original rib direction. It would appear, however, to be rursiradiate at the umbilical shoulder, then becoming straight and rectiradiate. There are occasional simple ribs on the last whorl and a few primary ribs with three, or in one case, four secondary ribs.

The ventral part of the peristome bears a short ribbed horn 4–5 mm. in length. It arises gradually from the venter and is not well preserved on either paratype.

REMARKS. The adult diameter of the macroconch and microconch, their rib density, and the development of the microconch horn, serve to distinguish this species from others. *P. (V.) smedmorensis* described below is considerably more coarsely ribbed than this species. As the highest beds of the underlying Scitulus Zone have hitherto yielded no ammonites, it is not possible to determine the origin of this species. The degree of variocostation of the macroconch is more pronounced than that of *P. (V.) scitulus*, but the general rib style of the two species shows some similarities. The very irregular costation of the body-chamber of the macroconch is a feature characteristic of many of the younger species of the subgenus *Virgatosphinctoides*. The development of the microconch horn in this species is not, however, very typical.

Pectinatites (Virgatosphinctoides) smedmorensis sp. nov.

(Pl. 15, figs. 1, 2)

DIAGNOSIS. Macroconchs approximately 150 mm. in diameter with following approximate rib densities: at 60 mm. diameter there are 39–41 ribs; at 65, 39–41; 70, 40–42; 75, 41–43; 80, 42. Ribs on inner whorls slender and prorsiradiate becoming rursiradiate with strengthening of primary ribs on body-chamber. Polygyrate, simple and intercalatory secondary ribs occur occasionally. Constrictions developed over last two whorls. Microconchs 86–107 mm. in diameter with following

approximate rib-densities: at 20 mm. diameter there are 34 ribs; at 25, 25; 30, 27; 35, 38. Ribs of inner whorls similar in style to macroconch, becoming a little coarser on outer whorl. Peristome bearing ventral horn up to 8 mm. long.

HOLOTYPE. Macroconch, plaster cast C·73430.

PARATYPE (ALLOTYPE). Microconch, plaster case C·73431.

MATERIAL. Five specimens, including three macroconchs (two of which are plaster casts, and two microconchs (both plaster casts)).

HORIZON. Both type specimens are from 22 ft. below the Blackstone.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, lower *Wheatleyensis* Zone, from 8 ft. above the Grey Ledge Stone Band, to 22 ft. below the Blackstone (A vertical range of 41 ft.).

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of approximately 150 mm. Diameter of the umbilicus approximately 85 mm. At 60 mm. diameter the holotype has 39 ribs; at 65, 39; 70, 40; 75, 41; 80, 42. (Text-fig. 6).

The ribs on the inner whorls are rectiradiate at the umbilical shoulder, then swing forwards to become fairly straight and prorsiradiate. The point of bifurcation of the ribs is fairly high on the whorl-side. The umbilical seam uncoils over the last half to three-quarters of a whorl.

The ribs on the outer whorl gradually lose their prorsiradiate tendency and become straight and slightly rursiradiate throughout their length. The primary ribs become more widely spaced and very sharp, and the development of the secondary ribs becomes irregular. There are occasional polygyrate, simple and intercalatory ribs.

There are several constrictions present. On the last half-whorl these are straight and are followed by a simple rib. The constrictions developed earlier are quite pronouncedly prorsiradiate, however. These oblique constrictions are preceded by a trifurcate rib which branches low on the whorl-side, and are followed by a simple rib.

A part of the suture line is present on one specimen; it is not well-preserved, however, but does show stout saddles and lobes. Both lateral lobes appear to be trifid.

The peristome is not completely preserved on any specimen but is presumably simple.

Microconch. Neither microconch is particularly well or completely preserved. Both specimens are plaster casts. The paratype is quite evolute and has a diameter of 86 mm. The diameter of the umbilicus is 36 mm. There are an estimated 46 primary ribs on the last whorl.

The ribs of the inner whorls are similar in style to those of the macroconch. At 20 mm. diameter there are 34 ribs; at 25, 35; 30, 37; 35, 38. (Text-fig. 6).

The outer whorl has ribs of similar style, but they become a little coarser. There is one possible constriction present at the aperture.

The ventral part of the peristome is damaged, but there is visible the basal 3 mm. of a horn, the original length of which may have been 7–8 mm.

REMARKS. Most characters of this species are sufficiently distinctive to separate

it from other species. It is distinguished from *P. (V.) clavelli* described above (p. 39) by the smaller adult size of the macroconch and the more coarsely-ribbed inner whorls. The microconch has a similar rib-density on its inner whorls to that of *P. (V.) woodwardi* (p. 45), but may be distinguished by the rib-style of both inner and outer whorls.

Pectinatites (Virgatosphinctoides) laticostatus sp. nov.

(Pl. 16)

DIAGNOSIS. Large *Virgatosphinctoides* developing massive widely-spaced primary ribs over last two whorls. Diameter 230–320 mm., with following approximate rib densities: at 20 mm. diameter there are 38 ribs; at 30, 42; 40, 45; 50, 47; 60, 48–52; 70, 49–55; 80, 49–55; 90, 47–56; 100, 45–53; 110, 43–51; 120, 40–49; 130, 38–45. Ribs of inner whorls rectiradiate to prorsiradiate becoming more widely spaced from ante-penultimate whorl onwards. Outer whorl extremely coarsely ribbed with abundant intercalatory secondary ribs. Microconch unknown.

HOLOTYPE. Plaster cast C.73416.

MATERIAL. Six specimens, including two plaster casts (all macroconchs).

HORIZON. Holotype from "dicey" shales 19 ft. below the Blackstone.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, lower Wheatleyensis Zone ranging from 3 ft. above the Grey Ledge Stone Band to 13 ft. 6 in. below the Blackstone (a vertical range of 47 ft.).

DESCRIPTION. Large evolute shell with a diameter of 232–320 mm. Diameter of umbilicus 130–180 mm. The holotype has 27 primary and approximately 68 secondary ribs on the last whorl. At 20 mm. diameter holotype has approximately 38 ribs; at 30, 42; 40, 45; 50, 47; 60, 48; 70, 49; 80, 49; 90, 47; 100, 45; 110, 43; 120, 40; 130, 38. The variation in rib density is shown in Text-fig. 5.

The ribs on the innermost whorls are rursiradiate at the umbilical shoulder then swing forwards to become rectiradiate or slightly prorsiradiate. A coarsening of the ribs develops very early, and the last three whorls become progressively more coarsely ribbed. There is a gradual loss of the initial rursiradial curve of the ribs and they become straight throughout their length. The point of bifurcation of the ribs is high on the whorl-side, and the angle of furcation is somewhat larger (at least on the outer whorls), than is usual in this subgenus. The umbilical seam uncoils over the last half whorl.

The outer whorl becomes extremely coarsely ribbed and abundant intercalatory secondary ribs are developed.

At least two constrictions are present on the holotype, one on the penultimate and one on the antepenultimate whorl; they are both strongly oblique. In each case the constriction is preceded by a biplicate rib, which branches very close to the umbilical shoulder. A simple rib follows the constriction.

The peristome is not preserved intact on the holotype, but is presumed to be simple.

The microconch of this species has not been found hitherto.

REMARKS. The very early development of widely-spaced ribs in this species is an uncommon character in this subgenus, and is therefore a very useful character for identification of this species. The problematical *Virgatosphinctoides nodiferus* Neaverson (1925 : 14, pl. 4, fig. 1) has a similar style of ribbing on its outer whorl, but its rib-development is not known in any detail. It is apparently geologically younger than *P. (V.) laticostatus*.

Pectinatites (Virgatosphinctoides) grandis (Neaverson)

(Pl. 15, fig. 3; Pl. 18)

1925 *Virgatosphinctoides grandis* Neaverson : 13, pl. 4, fig. 2.

MATERIAL. Eight specimens; seven macroconchs, one possible microconch.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, upper part of Wheatleyensis Zone, between 3 and 17 ft. below the Blackstone.

DESCRIPTION. *Macroconch*. There is good agreement between one of the specimens here figured (Pl. 18) and the holotype, which came from Corton, Dorset. The former has a diameter of 365 mm. The umbilicus has a diameter of 168 mm. There are 24 primary and approximately 82 secondary ribs on the last whorl. At 80 mm. diameter there are 86 ribs, at 90, 87; 100, 85; 110, 85; 120, 79; 130, 77; 140, 71; 150, 68; 160, 64. The variation in rib-density of the Kimmeridge forms is shown in Text-fig. 5.

The ribs on the inner whorls are rursiradiate at the umbilical shoulder and gradually swing forwards, so that less than half way up the whorl-side they become prorsiradiate. On the last umbilical whorl the ribs become more widely spaced, until on the outer whorl the primary ribs are very strong and distant from one another.

There are often large numbers of secondary ribs to each primary rib. On some specimens there are regularly as many as five secondary ribs to each primary rib. The ribs become straighter on the last part of the body-chamber and slightly prorsiradiate throughout their length. The secondary ribs tend to become less prominent and several primary ribs may be unbranched. Some intercalatory secondary ribs are usually present on the last whorl. There are several constrictions present. They are preceded by a compound rib, and followed by a simple rib.

The peristome is presumably simple.

Microconch. The figured microconch comes from the same horizon (17 ft. below the Blackstone) as the earliest recorded macroconch of this species.

It is 112 mm. in diameter. The diameter of the umbilicus is 45 mm. There are approximately 70 primary ribs on the last whorl. At 40 mm. diameter there are approximately 68 ribs. The ribs of the inner whorl are similar in style to those of macroconch. The outer whorl is similarly ribbed, but has occasional simple and polygyrate ribs and at least one constriction. The aperture bears a horn which projects from the venter by about 7 mm.

REMARKS. There is a great disparity in size between the microconch (112 mm. diameter) and the associated macroconch (approximately 280 mm. diameter). However, it has been found that as a general rule the microconch is usually slightly

coarser-ribbed than its macroconch at the same diameter. In this case the microconch has 68 ribs at 45 mm. diameter while the macroconch has approximately 70 at this diameter. No other fine-ribbed macroconchs occur at this horizon, so that there can be little doubt that this specimen is the microconch of *P. (V.) grandis*.

The size of this species, coupled together with rib-style and density distinguish it from other species of the genus.

***Pectinatites (Virgatosphinctoides) grandis acceleratus* subsp. nov.**

(Pl. 19)

DIAGNOSIS. Very large *Virgatosphinctoides*. General characters similar to *P. (V.) grandis* (Neaverson) but development of modified ornament occurring earlier. Ribs of outer whorl blunt and massive with few secondaries. Some intercalatory secondary ribs.

HOLOTYPE. Macroconch C.73422, the only specimen.

HORIZON. 13 ft. above the Rope Lake Head Stone Band. (Upper Kimmeridgian, basal part of Hudlestoni Zone).

DESCRIPTION. Large evolute shell with a diameter of approximately 375 mm. Diameter of the umbilicus 175 mm. There are 23 primary and approximately 60 secondary ribs on the last whorl.

This subspecies is similar in most respects to *P. (V.) grandis* described above. It differs in that it becomes coarser-ribbed earlier in development, but the different types of sculpture present in *P. (V.) grandis* are repeated in the same order, but at smaller diameters.

The peristome is simple.

REMARKS. This subspecies is closely related to *P. (V.) grandis* and must be interpreted as a direct derivative of it. There is, however, a thickness of approximately 35 ft. of rock between the highest recorded occurrence of *P. (V.) grandis* and the horizon from which this subspecies came. Most of the intervening rocks, however, are extremely poorly fossiliferous, so that collection failure is most probably responsible for the "break".

No microconch of this subspecies has been found hitherto.

***Pectinatites (Virgatosphinctoides) woodwardi* (Neaverson)**

(Pl. 20)

1925 *Allovirgatites woodwardi* Neaverson : 31, pl. 3, fig. 1.

1925 *Allovirgatites robustus* Neaverson : 32, pl. 3, fig. 3.

1925 *Allovirgatites versicostatus* Neaverson : 32, pl. 3, fig. 4.

1926 *Allovirgatites woodwardi* Neaverson ; Buckman, pl. 637.

MATERIAL. Eleven specimens (five macroconchs, six microconchs).

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Wheatleyensis Zone (just above the middle), ranging between 15 and 9 ft. below the Blackstone.

DESCRIPTION. *Macroconch*. Fairly evolute shell with a diameter of 150–185 mm. Diameter of umbilicus 74–88 mm. The last whorl of the specimen here figured which is approximately 155 mm. diameter has an estimated 46 primary and 111 secondary ribs. The innermost whorls are not completely preserved in any specimen. At 50 mm. diameter there are 49 ribs, at 55, 52; 60, 54; 65, 55; 70, 56. (Text-fig. 4).

The ribs on the inner whorls are rursiradiate at the umbilical shoulder, then swing forwards to become rectiradiate or slightly prorsiradiate and more or less straight. The point of bifurcation of the ribs is high on the whorl-side.

The umbilical seam uncoils over the last half-whorl. (This uncoiling is not noticeable in the plate reproduced herein, owing to the crushing of the last umbilical whorl which gives an incorrect impression of the amount of this whorl exposed.)

The ribs on the outer whorl become more widely spaced and stouter. The point of furcation is sometimes lower on the whorl-side. The number of secondary ribs per primary is variable, with as many as four secondary ribs to each primary rib. There are at least two possible constrictions on the outer whorl. The peristome is not preserved intact on any specimens, but is presumably simple.

Microconch. Fairly evolute shell with a diameter of approximately 68–77 mm. The diameter of the umbilicus is 25–30 mm. The figured specimen has 49 primary and an estimated 92 secondary ribs on its last whorl. At 20 mm. diameter there are approximately 34 ribs; at 25, 35; 30, 36. The variation in rib density is shown in Text-fig. 4.

The inner whorls are similar in rib style to those of the macroconch. The umbilical seam uncoils over the last half whorl (not well-shown on the figured microconch).

The ribs of the outer whorl lose most of their initial rursiradial curve and are almost straight and rectiradiate. There is some slight variability in the rib direction, however, from slightly rursiradiate to slightly prorsiradiate. There are occasional simple and trifurcate ribs on the last whorl.

The peristome is not preserved intact on any one specimen. The figured specimen shows it to be more or less straight, however. The ventral part of the peristome on this specimen projects about 2 mm. and is then broken, so that it is safe to conclude that a horn was originally present.

REMARKS. The Dorset specimens agree closely with Neaverson's figure of *Allo-*virgatites woodwardi**. *A. robustus* Neaverson is merely an incomplete specimen of the same species, apparently a little thicker-whorled, but still very close to the former species. *A. versicostatus* Neaverson is also very close to this species and may possibly be the microconch. The differences do not appear to be sufficient to warrant specific distinction. The association of *P. (V.) woodwardi* with *P. (V.) wheatleyensis* (Neaverson) is also indicative of the similarity of the Dorset to the Oxford material.

Pectinatites (Virgatosphinctoides) wheatleyensis Neaverson

(Pl. 21)

1925 *Virgatosphinctoides wheatleyensis* Neaverson : 12, pl. 1, fig. 1.

1956 *Subplanites (Virgatosphinctoides) wheatleyensis* (Neaverson) Arkell : 779, pl. 40, fig. 1.

MATERIAL. Eleven specimens (five macroconchs, six microconchs).

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Wheatleyensis Zone (just above the middle), ranging from 15 to 9 ft. below the Blackstone.

DESCRIPTION. *Macroconch*. One specimen from Kimmeridge here figured, (Pl. 21, fig. 1) agrees extremely closely with the holotype figured by Neaverson. It has a diameter of 132 mm. The diameter of the umbilicus is 57 mm. There are approximately 64 primary and 156 secondary ribs on the last whorl. Another specimen, which has well preserved inner whorls, has rib density as follows: at 25 mm. diameter there are 54 ribs, 30, 54; 35, 55; 40, 57; 45, 58; 50, 58; 55, 60. The variation in rib density of the Kimmeridge specimens is shown in Text-fig. 6.

The ribs on the inner whorls are rursiradiate at the umbilical shoulder, then swing forwards to become rectiradiate or slightly prorsiradiate. The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils on the last half whorl.

The outer whorl is very variable. The primary ribs become more widely spaced and are mostly polygyrate in some specimens. Others show the persistence of a more conservative type of ribbing, with more bifurcate than polygyrate ribs.

One specimen shows the last few approximated suture lines, but as these are extremely poorly preserved, comparison with the suture line figured by Neaverson (1925, text-fig. B, 5) is not possible. However, it can be seen from these suture lines that the body-chamber is half a whorl in length.

The peristome is simple and straight.

Microconch. One specimen figured herein (C. 73426) has a diameter of 91 mm. The diameter of the umbilicus (which is somewhat elongated by crushing) is 36 mm. There are 56 primary and 122 secondary ribs on the last whorl. The inner whorls are badly preserved, so that it is not possible to determine the rib density accurately. There are, however, approximately 50 ribs at 35 mm. diameter. The other figured specimen (C. 73427) has at 15 mm. diameter 47 ribs, at 20, 47; 25, 48; 30, 49. (Text-fig. 6).

The ribs on the inner whorls are of a similar style to the macroconch. The umbilical seam uncoils over the last half whorl (which appears to correspond to the length of the body-chamber).

The ribs on the outer whorl become slightly coarser, and there is the development of occasional polygyrate and simple ribs.

The peristome bears a horn when completely preserved, and this is 17 mm. long on specimen C. 73426. It is quite strongly ribbed.

REMARKS. The horizon at which this species occurs in Dorset is much lower than that quoted by Arkell (1947 : 71). Although the ammonites from just below the Basalt Stone Band are undoubtedly somewhat similar in appearance to this species, the outer whorls are not the same. The associated fauna also confirms the identity of this species. Neaverson placed his Wheatleyensis Zone immediately above the *Gravesia* Zones, which is too low in the succession.

Pectinatites (Virgatosphinctoides) wheatleyensis minor subsp. nov.

(Pl. 24, fig. 1)

DIAGNOSIS. Macroconchs small (103–108 mm. diameter) with following approxi-

mate rib densities: at 25 mm. diameter there are 44 ribs; at 30, 48; 35, 46; 40, 48; 45, 49. Ribs of inner whorls slender and approximately rectiradiate. Outer whorl developing strengthened primary ribs, remaining approximated, with polygyrate furcation predominant.

HOLOTYPE. Macroconch C.73429.

MATERIAL. Two specimens (both macroconchs).

HORIZON. Both specimens from 17 ft. below the Blackstone (Upper Kimmeridgian, middle Wheatleyensis Zone).

DESCRIPTION. Evolute shell with a diameter of 103-108 mm. (small for a macroconch). Diameter of umbilicus 43-45 mm. There are approximately 53 primary and 144 secondary ribs on the last whorl. In rib style this subspecies is very similar to *P. (V.) wheatleyensis*, but is somewhat more coarsely ribbed. At 20 mm. diameter there are approximately 44 ribs, at 30, 45; 35, 46; 40, 48; 45, 49. The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils over the last half-whorl. The ribs on the outer whorl are identical in style with those of the holotype of *P. (V.) wheatleyensis*, being mostly polygyrate.

The peristome is simple.

REMARKS. The microconch of this subspecies is not known. Apart from the somewhat more coarsely ribbed inner whorls, and smaller adult size, this subspecies is similar to *P. (V.) wheatleyensis*. Its lower stratigraphical horizon suggests that it is a possible ancestor of this species.

Pectinatites (Virgatosphinctoides) wheatleyensis delicatulus (Neaverson)

(Pl. 27, fig. 2)

1925 *Virgatosphinctoides delicatulus* Neaverson: 15, pl. 1, figs. 2 and ?3.

1925 *Allovirgatites tutcheri* Neaverson: 30, pl. 3, fig. 2.

1926 *Allovirgatites tutcheri* Neaverson; Buckman, pl. 692.

MATERIAL. Five specimens (four macroconchs, one possible microconch).

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Wheatleyensis Zone (upper part) between 7 and 4 ft. below the Blackstone (see below).

DESCRIPTION. *Macroconch*. The Dorset specimens agree closely with Neaverson's figure of the holotype, but are complete individuals. One specimen with a diameter of approximately 130 mm. and an umbilical diameter of 53 mm. has about 78 primary and 151 secondary ribs on the last whorl. The ribs on the inner whorl are a little finer and more dense than those of *P. (V.) wheatleyensis*. Some specimens have several constrictions of the last umbilical and the outer whorl.

The main point of difference between this subspecies and *P. (V.) wheatleyensis* lies in the more finely ribbed outer whorl, and the constrictions which are usually present. The constrictions are preceded by a polygyrate or polyploke rib and are followed by a simple rib. In some cases this rib is prominent like the flare of *Lytoceras*. (As is the case with Neaverson's examples).

The peristome is simple. The body-chamber is a half whorl in length.

Microconch. A single poorly preserved specimen from 5 ft. below the Blackstone is possibly the microconch of this subspecies. It is 91 mm. in diameter, has an umbilical diameter of 35 mm. and has approximately 56 primary and 112 secondary ribs on the last whorl. The inner whorls are so hidden by pyrite aggregates, however, that it cannot be with certainty referred to this subspecies.

The umbilical seam uncoils over the last half whorl. The peristome is missing, but was presumably originally horned.

REMARKS. *Allovirgatites tutcheri* Neaverson differs from *Virgatosphinctoides delicatulus* Neaverson by no more than the difference between two individuals of the same species. The general similarity to *P. (V.) wheatleyensis* justifies separation only at subspecific level.

This subspecies, which is stratigraphically a little younger than *P. (V.) wheatleyensis*, is certainly a derivative of it. One specimen which I refer to *P. (V.) wheatleyensis* is similarly ribbed to this subspecies on the inner whorls, but is intermediate between the two forms in the ribbing of its outer whorl.

Several very poorly preserved ammonites from the shales 4-10 ft. above the Blackstone are provisionally included in this subspecies.

Pectinatites (Virgatosphinctoides) pseudoscruposus (Spath)

(Pl. 17)

1936 *Subplanites pseudoscruposus* Spath : 173, fig. 2.

1947 *Subplanites pseudoscruposus* Spath ; Arkell : 77, fig. 17, 1.

EMENDED DIAGNOSIS. Diameter of shell 220-230 mm. with following rib densities : at 40 mm. diameter there are approximately 51 ribs ; at 50, 53-57 ; 60, 55-61 ; 70, 60-66 ; 80, 66-71 ; 90, 70-76 ; 100, 75-78. Ribs on inner whorls slender and prorsiradiate. Outer whorl developing massive blunt primary ribs typically with virgatotome furcation, with up to six secondary ribs to each primary.

MATERIAL. Six specimens (all macroconchs).

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Wheatleyensis Zone (upper part), between 9 and 3 ft. below the Blackstone.

DESCRIPTION. Large evolute shell with a diameter of 220 to approximately 230 mm. Diameter of umbilicus 110-115 mm. The specimen figured herein (C.73418) has 36 primary and approximately 104 secondary ribs on the last whorl (about one-eighth of a whorl is missing).

At 50 mm. diameter this specimen has 57 ribs, at 60, 59 ; 70, 66 ; 80, 72 ; 90, 76 ; 100, 77 ; 110, 78. The variation in rib density is shown in Text-fig. 5.

The ribs on the inner whorls are fine and slender. They are curved rursiradially at the umbilical shoulder, but swing forwards rapidly to become prorsiradiate and almost straight. The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils over the last half to three-quarters of a whorl.

The sculpture of the outer whorl is extremely variable, no two specimens being alike in this respect. Typically there are developed very prominent blunt primary

ribs which tend to become virgatotome, with up to six secondary ribs. There are occasional simple and intercalatory secondary ribs.

Constrictions are also present on the last whorl of some specimens of this species. These are preceded by a virgatotome rib with four or five secondary ribs, and are followed by a simple rib.

The microconch of this species is unknown.

REMARKS. The validity of this species may be questioned, as it does not entirely fulfil the requirements of Article 13 of the International Code of Zoological Nomenclature. However, the outer whorl fragment upon which Spath based this species is absolutely characteristic and there can be no doubt of its interpretation. Spath's figure is misleading in that the inner whorls he associated with the outer whorl fragment almost certainly belong to a different species. The name of this species is well-known to those familiar with British Kimmeridgian ammonites, and there would seem to be little to be gained by rejecting a name because its original description was legally defective. The intention here has been to give a more satisfactory definition of the species by figuring a more complete specimen and giving a comprehensive description.

Pectinatites (Virgatosphinctoides) reisiiformis sp. nov.

(Pl. 22; Pl. 23, fig. 3)

DIAGNOSIS. Macroconchs 155-255 mm. in diameter with following rib densities: at 20 mm. diameter there are 48-52 ribs, at 25, 49-54; 30, 52-56; 35, 54-58; 40 55-58; 45, 56-59; 50, 57-61; 55, 58-63; 60, 59-64; 65, 60-65; 70, 61-66. Ribs of inner whorls slender and prorsiradiate. Outer whorl becoming suddenly more coarsely-ribbed with polygyrate then virgatotome ribs, with abundant simple and intercalatory secondary ribs. Microconchs 78-110 mm. in diameter with following rib densities: at 20 mm. diameter there are approximately 42 ribs; at 25, 42-44; 30, 43-46; 35, 44-47; 40, 46-49; 45, 48-52. Ribs of inner whorls similar to macroconch. Outer whorl more coarsely ribbed with occasional simple and polygyrate ribs and intercalatory secondaries. Peristome with ventral horn 10-20 mm long.

HOLOTYPE. Macroconch C.73435.

PARATYPE (ALLOTYPE). Microconch C.73436.

MATERIAL. Twenty-five specimens (seventeen macroconchs, eight microconchs).

HORIZON. Both holotype and paratype are from shales 13 ft. above the Rope Lake Head Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, uppermost Wheatleyensis and basal Hudlestoni Zones, from 6 ft. above the Blackstone to 16 ft. above the Rope Lake Head Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 155-255 mm. Diameter of umbilicus 65-118 mm. The holotype has a diameter of 174 mm., and an umbilical diameter of 76 mm. There are 51 primary and 118 secondary ribs on

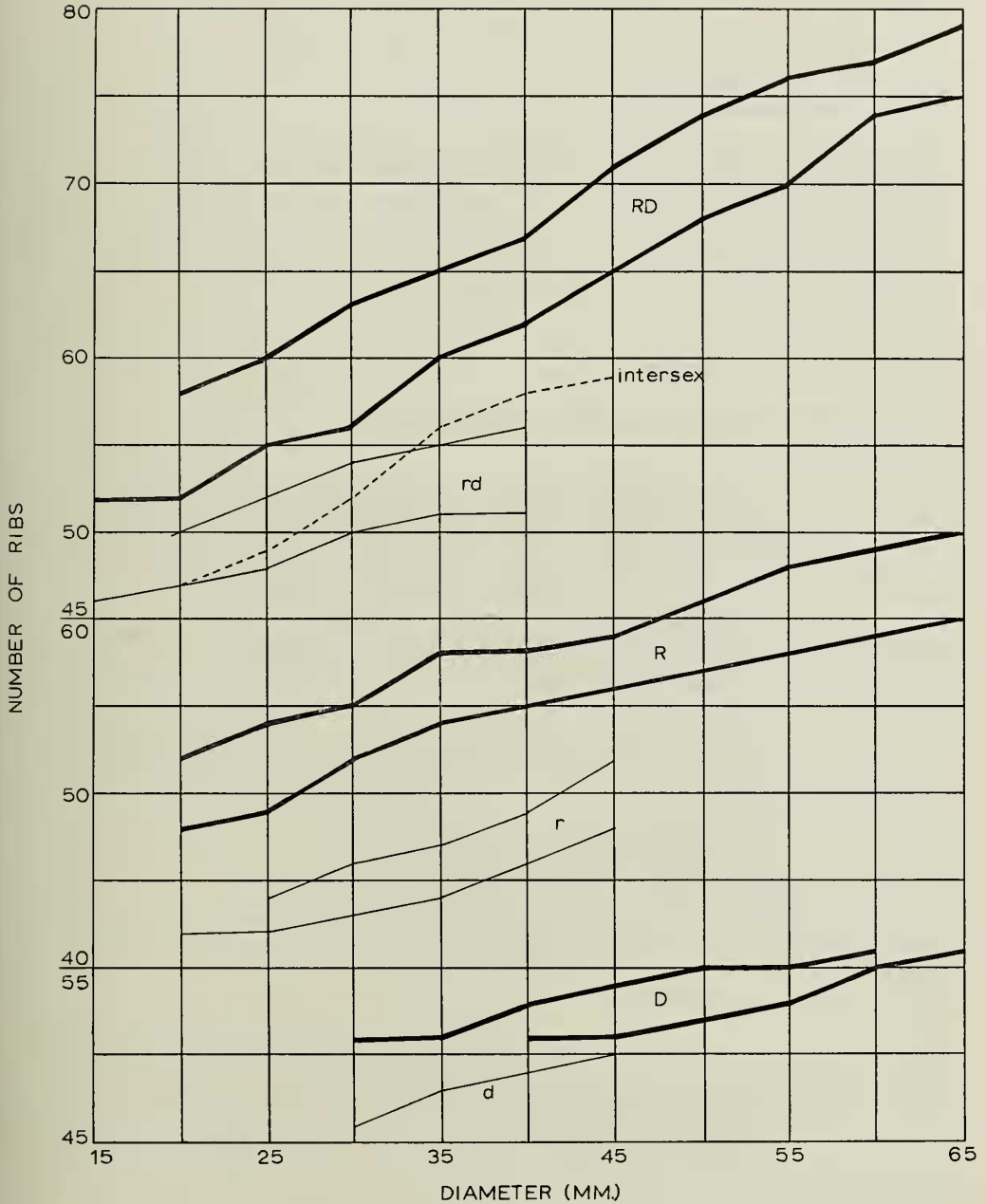


FIG. 7. Rib density of species of the subgenus *Virgatosphinctoides*. Upper case letters : macroconchs ; lower case letters : microconchs. RD, rd : *P. (V.) reisisiformis densicostatus* ; R, r : *P. (V.) reisisiformis* ; D, d : *P. (V.) donovani*.

the last whorl. The inner whorls are well preserved on the holotype. At 20 mm. diameter there are 48 ribs, at 25, 49; 30, 52; 35, 54; 40, 55; 45, 56; 50, 57; 55, 58; 60, 59; 65, 60; 70, 61; 75, 62. The variation in rib density is shown in Text-fig. 7.

The ribs on the inner whorls are dense and slender. They are rursiradiate at the umbilical shoulder, then swing forwards to become prorsiradiate (pronouncedly so in some specimens). The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils over the last half to three-quarters of a whorl.

On the outer whorl the ribs become rather suddenly more widely spaced. At first, polygyrate ribs are developed; then as the primary ribs become stouter and blunter, the branching has a tendency towards the virgatotome condition, with up to four secondary ribs to each primary rib. There are abundant simple and intercalatory ribs on the last whorl.

The ribbing of the outer whorl is extremely variable in this species. No two specimens are alike in this respect. Some of the larger specimens are obviously gerontic individuals, the last secreted half whorl or so of their shell being almost devoid of ornament.

The peristome is not preserved on the holotype, but other specimens show it to be straight and simple.

Microconch. Evolute shell with a diameter of 78–110 mm. The diameter of the umbilicus varies from 30–42 mm. The paratype is 110 mm. in diameter and has an umbilical diameter of 42 mm. There are 63 primary and 126 secondary ribs on the last whorl of the paratype. At 25 mm. diameter the paratype has 44 ribs, at 30, 45; 35, 47; 40, 48. The variation in rib density is shown in Text-fig. 7.

The ribs of the inner whorls are similar in style to those of the macroconch, but tend not to be so markedly prorsiradiate. The point of bifurcation of the ribs is a little lower on the whorlside than on the macroconchs. The umbilical seam uncoils over the last half whorl.

The outer whorl becomes more coarsely ribbed, and there is a tendency for the ribs to become somewhat flexuous. At, or just below the point of furcation, the ribs bend back a little. This feature is well shown on the paratype. Almost all the ribs on the outer whorl are bifurcate, but there are very occasional simple, polygyrate, and intercalatory ribs.

The peristome is somewhat sinuous, and laterally extends anteriorly a little. There is a well developed ventral horn, which is often feebly ribbed. On the paratype the horn projects from the venter by about 18 mm. In some specimens growth has proceeded a little beyond the horn; this anteriorly extended portion of the shell shows little or no ornamentation.

REMARKS. The density of the ribbing on the inner whorls, and the sculpture of the outer whorl are distinctive features of this species. It may be derived from *P. (V.) wheatleyensis* but shows considerably more variocostation than this latter species. The diversity of the ornamentation of the body-chamber of the macroconchs contrasts with the rib-density of the inner whorls which are remarkably similar in rib style and density.

Pectinatites (Virgatosphinctoides) reisiiformis densicostatus subsp. nov.

(Pl. 23, figs. 1, 2; Pl. 24, fig. 2)

DIAGNOSIS. Macroconchs 150–195 mm. in diameter with following rib densities: at 20 mm. diameter there are 52–58 ribs; at 25, 55–60; 30, 56–63; 35, 60–65; 40, 62–67; 45, 65–71; 50, 68–74; 55, 70–76; 60, 73–77; 65, 75–79. Ribs of inner whorls slender and prorsiradiate. Outer whorl developing strengthened primary ribs, first with polygyrate and polyploke furcation, then with tendency to virgatotome furcation. Microconchs 77–110 mm. diameter with following rib densities: at 20 mm. diameter there are 47–50 ribs; at 25, 48–52; 30, 50–54; 35, 51–55; 40, 51–56. Ribs of inner whorls slender and prorsiradiate, becoming somewhat coarser on outer whorl with occasional polygyrate and simple ribs. Peristome with ventral horn 12–24 mm. long.

HOLOTYPE. Macroconch C.73437.

PARATYPE. Microconch C.73438.

MATERIAL. Twenty-eight specimens (fourteen macroconchs, thirteen microconchs, one intersex).

HORIZON. Both holotype and paratype from shales 13 ft. above the Rope Lake Head Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, lower part of Hudlestoni Zone, 12–16 ft. above the Rope Lake Head Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 150–195 mm. Diameter of the umbilicus 63–87 mm. The holotype is 157 mm. in diameter and has an umbilical diameter of 67 mm. There are 64 primary and 141 secondary ribs on the last whorl. At 15 mm. diameter there are about 52 ribs; at 20, 58; 25, 60; 30, 63; 35, 63; 40, 65; 45, 65; 50, 68; 55, 70; 60, 74; 65, 75. The variation in rib density is shown in Text-fig. 7.

In style of ribbing on both inner and outer whorls this subspecies agrees closely with the description of *P. (V.) reisiiformis* given above (p. 50). It differs, however, in being far more densely ribbed throughout. The ribs themselves are also a little more slender.

Microconch. Evolute shell with a diameter of 77–110 mm. Diameter of the umbilicus 27–42 mm. The paratype has a diameter of 83 mm. and an umbilical diameter of 30 mm. There are 67 primary and 132 secondary ribs on the last whorl. At 15 mm. the paratype has an estimated 46 ribs, at 20, 50; 25, 50; 30, 52. The variation in rib density is shown Text-fig. 7.

The rib style on the inner whorls is similar to that of the microconch of *P. (V.) reisiiformis*, but the ribs are usually a little more prorsiradiate and are more slender.

On the outer whorl the ribs become a little coarser, and occasional polygyrate and simple ribs are developed.

The peristome margin may be straight or sinuous, a horn is developed ventrally, and on the paratype projects from the venter by 16 mm. In some cases growth has proceeded a little beyond the growth of the horn, and there is a fairly smooth zone

anterior to this. In other cases a further horn may be grown close to the first one.

Intersex. This subspecies is particularly interesting because of a probable mutation which arose resulting in the development of inter-sexual individuals. One specimen (C.73439, Pl. 24, fig. 2) is intermediate in size between macroconch and microconch (117 mm. diameter) and has rib density of a typical microconch up to a diameter of 30 mm. (20, 47; 25, 49; 30, 52). Thereafter it becomes more finely ribbed (35, 56; 40, 58), and is intermediate between macroconch and microconch in rib density. (Text-fig. 7).

At a diameter of 94 mm. a horn is developed, and beyond this there is about three-eighths of a whorl of coarsely ribbed shell with sculpture similar to the outer whorls of a macroconch, but bearing four further horns. The development in this subspecies of the macroconch outer whorl sculpture at such a small diameter is unique to this specimen.

In addition to the above specimen which is absolutely intermediate in character between macroconch and microconch, three other specimens show a slight degree of intersexuality. These three specimens are apparently normal macroconchs to judge by their size, rib density and sculpture. They do, however, develop a type of horn in the later stages of development; this appears at a diameter of 140-150 mm. and is unlike the true microconch horn in that it is developed from a single rib, has negligible ventral projection but projects laterally some distance down the whorl side. In addition, the diameter at which these structures are developed is much greater than that at which the true horn of the microconch occurs.

These three latter specimens possess some degree of microconch character.

REMARKS. This subspecies shows a general similarity to *P. (V.) reisiiformis* described above. It may readily be distinguished, however, by the rib density of the inner whorls. Because of this likeness to *P. (V.) reisiiformis*, the similar horizon of the two forms (this subspecies is confined to the beds yielding the youngest specimens of *P. (V.) reisiiformis*) tends to confirm the view that it should be considered a direct derivative of *P. (V.) reisiiformis*.

Pectinatites (Virgatosphinctoides) abbreviatus sp. nov.

(Pl. 26, fig. 3)

DIAGNOSIS. Macroconchs small (113-125 mm. in diameter) with following rib densities: at 20 mm. diameter there are 40-42 ribs; at 25, 41-43; 30, 42-44; 35, 44-45; 40, 45-46; 45, 46. Ribs on inner whorls slender, rursiradial to rectiradial. Primary ribs becoming more widely spaced and stronger on outer whorl, with development of simple and polygyrate ribs. Microconchs unknown.

HOLOTYPE. Macroconch C.73440.

MATERIAL. Three specimens (all macroconchs).

HORIZON. Holotype from shales 20 ft. above the Rope Lake Head Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Hudlestoni Zone (lower part), 20-22 ft. above the Rope Lake Head Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 113–125 mm. Diameter of umbilicus 45–59 mm. The holotype has a diameter of 113 mm. and an umbilical diameter of 45 mm. There are 47 primary and 96 secondary ribs on the last whorl. At 15 mm. diameter the holotype has 39 ribs; at 20, 40; 25, 41; 30, 42; 35, 44; 40, 45; 45, 46. The variation in rib density is shown in Text-fig. 6.

The ribs on the inner whorls are rursiradiate at the umbilical shoulder, they then bend forwards to become rectiradiate. Some of the ribs are, however, rursiradiate throughout their length. The point of bifurcation is high on the whorl-side. The umbilical seam uncoils over the last half whorl.

On the outer whorl, the ribs gradually become coarser, and on the last half whorl (which to judge by differences in the crushing corresponds to the length of the body-chamber) the primary ribs become widely spaced. Several simple, polygyrate and intercalatory ribs are developed.

The peristome is damaged on all the specimens, but on the holotype it is partially preserved and appears to be straight and simple.

The microconch of this species is unknown.

REMARKS. This species is notable for the small size at which the macroconch becomes mature. For this reason it is unlikely to be confused with any other species of the genus. *P. (V.) wheatleyensis minor* is of similar size, but the outer whorl of this subspecies is ornamented by approximated mainly polygyrate ribs; this contrasts with the more widely spaced primary ribs of *P. (V.) abbreviatus*.

Pectinatites (Virgatosphinctoides) donovani sp. nov.

(Pl. 25, figs. 1, 2)

DIAGNOSIS. Macroconchs 132–155 mm. in diameter with following rib densities: at 30 mm. diameter there are approximately 51 ribs; at 35, 51; 40, 51–53; 45, 51–54; 50, 52–55; 55, 53–55; 60, 55–56. Ribs on inner whorls slender and porsiradiate. Outer whorl with strong irregular primary ribs with frequent polygyrate furcation. Simple and intercalatory secondary ribs abundant. Ribs fading slightly over last quarter of whorl. Microconchs 99–106 mm. in diameter with following approximate rib densities: at 30 mm. diameter there are 46 ribs; at 35, 48; 40, 49; 45, 50. Ribs of inner whorls similar to macroconch. Outer whorl developing somewhat stronger ribs with occasional simple and intercalatory ribs and polygyrate furcation.

HOLOTYPE. Macroconch C.73441.

PARATYPE (ALLOTYPE). Microconch C.73442.

MATERIAL. Ten specimens, all plaster casts, (six macroconchs, four microconchs).

HORIZON. Holotype from 30 ft. and paratype from 36 ft. below the Basalt Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Hudlestoni Zone (middle part), 30–40 ft. below the Basalt Stone Band.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 132-155 mm. The diameter of the umbilicus varies from 59-69 mm. The holotype has a diameter of 137 mm. and an umbilical diameter of 65 mm. The last whorl of the holotype has 46 primary and 101 secondary ribs. At 40 mm. diameter the holotype has 52 ribs, at 45, 53; 50, 53; 55, 54; 60, 55; 65, 56. The variation in rib density is shown in Text-fig. 7.

The ribs on the inner whorl are rectiradiate at the umbilical shoulder, then curve forwards to become fairly straight and prorsiradiate. At the point of bifurcation, which is high on the whorl-side, the ribs curve back a little to the rectiradiate position. The umbilical seam uncoils over the last half to three-quarters of a whorl.

On the outer whorl the ribs gradually lose their initial rursiradial curve. The primary ribs become very strong and irregular, and the point of furcation is lower on the whorl-side. There are abundant simple, polygyrate and intercalatory ribs on the last whorl. Over the last quarter of a whorl, the ribs tend to fade somewhat, and although easily distinguishable, are not so prominent.

The peristome is somewhat sinuous and is simple.

Microconch. Evolute shell with a diameter of 99-106 mm. Diameter of the umbilicus 42-47 mm. The paratype has a diameter of 105 mm. and an umbilical diameter of 45 mm. The last whorl of the paratype has 49 primary and 96 secondary ribs. At 30 mm. diameter the paratype has 46 ribs, at 35, 48; 40, 49; 45, 50. The variation in rib density is shown in Text-fig. 7.

The ribs on the inner whorls are of similar style to those of the macroconch. The umbilical seam uncoils over the last half whorl (which appears to correspond to the length of the body-chamber, to judge by differences in the degree of crushing).

On the outer whorl the ribs become rather suddenly more widely spaced half a whorl from the aperture. These coarser ribs are rather irregular in their furcation; most are bifurcate, but there are several simple, polygyrate and intercalatory ribs.

The peristome is not completely preserved on any microconch of this species. The dorsal part of it appears to be straight, but no specimen shows the whole of the ventral part which was presumably horned. The ventral part of the peristome of the paratype appears to project by some 5 mm., but is not well-preserved at this point.

REMARKS. This species appears to be the one misidentified by Arkell as *P. (V.) wheatleyensis* (Arkell 1956 : 21). As I have shown earlier, however (p. 47), the true *P. (V.) wheatleyensis* occurs considerably lower in the succession, where it is associated with other species also characteristic of the Nodule Bed of Wheatley. The rib density and ornamentation of the body-chamber of *P. (V.) donovani* distinguish it from *P. (V.) wheatleyensis*.

***Pectinatites (Virgatosphinctoides) magnimasculus* sp. nov.**

(Pl. 29)

DIAGNOSIS. Microconchs very large (175-185 mm. in diameter) with following approximate rib densities: at 25 mm. there are 54 ribs; at 30, 55; 35, 57; 40, 57; 45, 59; 50, 60; 55, 62; 60, 62. Ribs of inner whorls slender, rectiradiate to slightly

prorsiradiate. Outer whorl with similar style of ribs, remaining approximated but becoming a little coarser. Peristome with ventral horn 12-15 mm. long.

HOLOTYPE. Microconch C.73443.

MATERIAL. Two specimens, both plaster casts, microconchs.

HORIZON. Holotype from 21 ft. below the White Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Hudlestoni Zone (upper part), 18-21 ft. below the White Stone Band.

DESCRIPTION. Large evolute shell with a diameter of 175-185 mm. Diameter of umbilicus 77-82 mm. The number of primary ribs on the last whorl is estimated as about 70. The holotype which is 175 mm. in diameter and which has an umbilical diameter of 77 mm. has at a diameter of 25 mm. 54 ribs; at 30, 55; 35, 57; 40, 57; 45, 59; 50, 60; 55, 62; 60, 62. (Text-fig. 6). The other specimen's inner whorls are too poorly preserved to measure rib density.

The ribs on the inner whorls are fine and slender. They are rursiradiate at the umbilical shoulder, then curve forwards to become straight and rectiradiate, or slightly prorsiradiate. The point of bifurcation of the ribs is high on the whorl-side. The umbilical seam uncoils over the last half whorl.

The ribbing on the outer whorl is similar to that on the inner whorls. There is gradual coarsening of the ribs over the last whorl, but they are still approximated right up to the aperture.

The peristome is straight and bears a horn 15 mm. long on the holotype. Two other horns are also visible on the last whorl of the holotype. These are 11 and 13 mm. in length, and are ribbed. The other microconch specimen has three horns which in order of age are 6+; 19 and 12+ mm. in length.

REMARKS. Members of this species include the largest known horned microconchs. It is interesting to note that the ribs on the last whorl differ very little in style and density from those of the earlier whorls. It seems probable that several of the larger species of the subgenus *Virgatosphinctoides*, of which no microconchs have been found hitherto, have microconchs similar in size to those of *P. (V.) magnismasculus*.

Associated with the two microconch specimens was found a fragment of a large macroconch, which if complete would have had a diameter of about 320 mm. Its fragmentary nature and extremely poor preservation are such, however, that it cannot be referred to this species with any certainty.

Pectinatites (Virgatosphinctoides) encombensis sp. nov.

(Pl. 27, fig. 1; Pl. 28)

DIAGNOSIS. Microconchs 70-103 mm. in diameter with following rib densities: at 20 mm. diameter there are 42-43 ribs; at 25, 43-47; 30, 44-49; 35, 46-52. Ribs of inner whorls very slender, rectiradiate to slightly prorsiradiate. Ribs on outer whorl gradually becoming a little more widely spaced, with abundant polygyrate furcation on body-chamber. Peristome with ventral horn 9-15 mm. in length. Macroconchs 155-215 mm. in diameter with following very approximate rib densities:

at 55 mm. diameter there are 52 ribs; at 60, 54; 65, 56; 70, 57; 75, 58; 80, 59; 85, 60; 90, 61; 95, 63; 100, 64; 105, 65; 110, 66; 115, 67. Ribs of inner whorls similar to microconch. Outer whorl developing strengthened primary ribs becoming more widely spaced with occasional simple and polygyrate ribs and intercalatory secondaries.

HOLOTYPE. Microconch, C.73444.

PARATYPE (ALLOTYPE). Macroconch C.73445.

MATERIAL. Ten specimens, all plaster casts (three macroconchs, seven microconchs).

HORIZON. Holotype from 21 ft. and paratype from 33 ft. below the White Stone Band.

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Hudlestoni Zone (upper part), 9-33 ft. below the White Stone Band.

DESCRIPTION. The holotype is a microconch, since no really adequately preserved macroconchs have been discovered.

Microconch. Evolute shell with a diameter of 70-103 mm. Diameter of the umbilicus 28-38 mm. The holotype has a diameter of 103 mm. and an umbilical diameter of 38 mm. There are 63 primary and approximately 133 secondary ribs on the last whorl of the holotype.

At 20 mm. diameter there are 43 ribs, at 25, 47; 30, 48; 35, 49. The variation in rib density is shown in Text-fig. 6.

On the inner whorls the ribs are very slender. They are rursiradiate at the umbilical shoulder, then bend forwards to become fairly straight and rectiradiate or slightly prorsiradiate. The umbilical seam uncoils over the last half whorl.

The outer whorl is similarly ribbed, but gradually the ribs become a little more widely spaced and a little thicker. Abundant polygyrate ribs are developed on the last half whorl which appears to correspond to the length of the body-chamber.

The peristome is fairly straight and bears a ventral horn which varies in length from 11-20 mm. The holotype and two other specimens have additional horns a little way back from the peristome. The holotype has a total of three horns which (in order of age) are 15, 15 plus and 11 mm. long.

Macroconch. Evolute shell with a diameter of 155-215 mm. Diameter of umbilicus 75-118 mm. The paratype is the only macroconch showing any detail of the inner whorls. It is 215 mm. in diameter and has an umbilical diameter of 118 mm. There are approximately 68 primary and 122 secondary ribs on the last whorl. At 55 mm. diameter there are an estimated 52 ribs; at 60, est. 54; 65, est. 56; 70, est. 57; 75, est. 58; 80, est. 59; 85, est. 60; 90, est. 61; 95, est. 63; 100, est. 64; 105, est. 65; 110, est. 66; 115, est. 67. (Text-fig. 6).

The ribs on the inner whorls appear to be of a style similar to those of the microconch; on the last umbilical whorl they appear straight and rectiradiate throughout their length. On the last half whorl the primary ribs become more widely spaced and prominent, and their furcation becomes irregular. Several polygyrate, simple and intercalatory ribs are developed.

The peristome is simple.

REMARKS. Since the inner whorls are poorly preserved, the macroconch cannot be matched with the microconch as far as rib densities of the inner whorls go, but their association and similar sculpture strongly suggest that they are dimorphs of the same species.

This species is distinguished from others by its rib style and density. It bears some resemblance to *P. (V.) reisiiformis* described above (p. 50) in rib density, but the ribs themselves are considerably more slender in *P. (V.) encombensis*. The macroconchs are not so variocostate as those of *P. (V.) reisiiformis*, which provides another basis for distinction between these two species.

Subgenus *PECTINATITES* Buckman 1922

SYNONYMS. *Wheatleyites* Buckman 1923; *Keratinites* Buckman 1925; ? *Pectiniformites* Buckman 1925 (see p. 20).

TYPE SPECIES. (By original designation). *Ammonites pectinatus* Phillips 1871.

DIAGNOSIS. Dimorphic. Microconchs generally finely ribbed on inner whorls, body-chamber usually more coarsely ribbed. Peristome with ventral horn often of great length. Macroconchs generally finely ribbed on inner whorls. Outer whorls variable, primary ribs typically strong with variable number of secondary ribs. Never truly virgatotome. Both macroconch and microconch show tendency for ribs to bifurcate very low on whorl side. Constrictions generally absent.

Upper Kimmeridgian, ?Wheatleyensis Zone, Pectinatus Zone.

Ammonites pectinatus Phillips was the first species, now included in this genus, to be described. Phillips' figure (1871, pl. 15, fig. 17) is very poor, and the holotype has been long thought to have been lost. Arkell (1956 : 780) therefore designated a topotype as the neotype.

Pectinatites (Pectinatites) inconsuetus sp. nov.

(Pl. 30)

DIAGNOSIS. Macroconchs approximately 150 mm. in diameter. Ribs on outer whorl bifurcate low on whorl side. Ornamentation gradually fading on body-chamber. Peristome straight. Microconchs approximately 100 mm. in diameter. At 50 mm. diameter there are approximately 50 ribs. Point of bifurcation of ribs becoming gradually lower on whorl-side towards last whorl. Body-chamber more coarsely ribbed than inner whorls. Peristome bearing short ventral horn.

HOLOTYPE. Macroconch C.73446.

PARATYPE (ALLOTYPE). Microconch C.73447.

MATERIAL. Two specimens, both plaster casts (one macroconch, one microconch).

HORIZON. Both specimens from 10 ft. above the Middle White Stone Band. Upper Kimmeridgian, lower Pectinatus Zone.

DESCRIPTION. *Macroconch*. Evolute shell with a diameter of 153 mm. Diameter of umbilicus 65 mm. There are 26 primary and approximately 83 secondary ribs on the last whorl.

The ribs on the inner whorls are not well preserved, but are seen to be rursiradiate at the umbilical shoulder, then swinging forwards to become straight and slightly prorsiradiate. The primary ribs on the outer whorl at first become more pronounced and are more widely spaced. They branch very low on the whorl-side, giving rise to up to four secondary ribs. There are abundant intercalatory secondary ribs, which also arise very low on the whorl-side.

Over the last quarter of a whorl, the ribs gradually fade and become very indistinct.

The peristome which is straight and simple inclines anteriorly towards the venter.

Microconch. Evolute shell with a diameter of 98 mm. Diameter of the umbilicus 32 mm. There are 50 primary and an estimated 110 secondary ribs on the last whorl. There are approximately 50 ribs at a diameter of 30 mm.

The ribs on the inner whorls are fine and slender. They are rursiradiate at the umbilical shoulder, then curve forwards to become rectiradiate or slightly prorsiradiate. The point of bifurcation of the ribs is high on the whorl-side.

The umbilical seam uncoils over the last half whorl.

The ribs on the outer whorl are similar in style to those of the inner whorls, but gradually the point of bifurcation of the ribs becomes much lower on the whorl-side. Over the last half-whorl the primary ribs become stronger and more widely spaced, and usually give rise to three secondary ribs on the whorl-side. There are several simple and intercalatory ribs on the last half whorl.

The peristome bears a horn. On the paratype this is broken, and the resultant broken end has not reproduced well in the plaster. The basal 4 mm. of the horn are just visible, however.

REMARKS. I earlier referred the macroconch of this species to the Tithonian genus *Pseudovirgatites* (Cope & Zeiss 1964 : 12). At the time of making this identification, however, the microconch had not been discovered. The style of ribbing of the macroconch is very similar to some specimens of *Pseudovirgatites* from Franconia. However, the microconch, with its broadly similar ribbing on its body-chamber and horned peristome, shows that this species belongs to the genus *Pectinatites*.

This again is an example of the remarkable homeomorphy between the Tithonian and Upper Kimmeridgian ammonites which has misled so many workers in the past. This species of *Pectinatites* with its type of modification of the ribbing on the body-chamber of the macroconch is unlikely to be confused with any other species.

Pectinatites (Pectinatites) eastlecottensis (Salfeld)

(Pl. 26, fig. 1)

- 1913 *Perisphinctes eastlecottensis* Salfeld : 429, pls. 41, 42.
 1914 *Perisphinctes eastlecottensis* Salfeld ; Salfeld : 130.
 1922 *Wheatleyites eastlecottensis* (Salfeld) Buckman : 28.
 1923 *Pectinatites aulacophorus* Buckman, pl. 381.
 1925 *Wheatleyites eastlecottensis* (Salfeld) ; Neaverson : 37.
 1933 *Pectinatites eastlecottensis* (Salfeld) Arkell : 457.

MATERIAL. Two specimens, plaster casts (both microconchs).

HORIZON. Ten feet above the Middle White Stone Band. Upper Kimmeridgian, lower *Pectinatus* Zone.

DESCRIPTION. Neither of the two specimens from Kimmeridge is complete. The more complete of the two (C.73449, Pl. 26, fig. 1) has a diameter of 70 mm. and an umbilical diameter of approximately 22 mm. On the last half whorl preserved there are an estimated 58 primary and 97 secondary ribs. This would mean that at a diameter of 70 mm. there are about 100 ribs on a complete whorl.

The holotype, which is a macroconch, has 130 ribs at 110 mm. diameter. The holotype of *P. aulacophorus* Buckman has (according to Buckman) about 97 ribs at 66 mm. diameter.

The noticeable feature on the Dorset specimens is that the ribs often bifurcate very close to the umbilical shoulder.

The peristome is not preserved on either of the Dorset specimens but was probably originally horned.

REMARKS. The extremely dense ribbing of this species is very characteristic. There can be little doubt that these Dorset specimens are the microconch of Salfeld's figured macroconch.

The holotype was quoted by Salfeld as coming from the Upper Lydite Bed at Swindon. Chatwin & Pringle (1921 : 166) later showed that in fact it came from the upper part of the Shotover Grit Sands. Buckman's species *P. aulacophorus* was quoted by him as occurring in his Bed 12 at Swindon—the bed which yielded the holotype of *P. eastlecottensis*.

Buckman's figure shows that the last sutures of *P. aulacophorus* are somewhat approximated, and that the umbilical seam is just beginning to uncoil. In this case it would appear that only the body-chamber is missing from this specimen, and it is, therefore, a microconch. Neaverson's figure (1925, pl. 1, fig. 5) of *P. aulacophorus* is an immature specimen of a species of the subgenus *Virgatosphinctoides* close to *P. (V.) wheatleyensis delicatulus*.

The occurrence of this species in Dorset enables good correlations to be made with Swindon and Oxford.

Pectinatites (Pectinatites) cf. groenlandicus (Spath)

(Pl. 31)

1936 *Pectinatites (Keratinites?) groenlandicus* Spath : 25, pl. 6, fig. 1.

MATERIAL. One specimen (macroconch).

HORIZON. Ten feet above the Middle White Stone Band. Upper Kimmeridgian, lower *Pectinatus* Zone.

DESCRIPTION. The single incomplete specimen from Kimmeridge has a crushed diameter of 380 mm. Diameter of umbilicus 177 mm. At 40 mm. diameter there are 48 ribs; at 50, 53; 60, 70, 80, 90, 51; 100, 52; 110, 120, 53; 130, 54; 140, 55; 150, 54; 160, 53; 170, 52.

There is a very close comparison between the Dorset specimen and the holotype which is from the Pectinatus Zone of Greenland. The furcation and style of the ribs on the inner whorls is very similar to that of the holotype (Spath, pl. 7, fig. 5). The point of bifurcation is very high on the whorl-side. The outer whorl is similar, too, with the ribs becoming less prominent towards the aperture of the shell. The peristome, which is not preserved, is presumably simple.

REMARKS. "*Wheatleyites*" *reductus* (Buckman) (1923, pl. 384) shows certain similarities to this species, but the inner whorls of this species are more sharply and densely ribbed.

***Pectinatites (Pectinatites) cornutifer* (Buckman)**

(Pl. 25, fig. 3; Pl. 26, fig. 2)

1925 *Keratinites cornutifer* Buckman: pl. 602.

1926 *Keratinites nasutus* Buckman: pl. 664.

MATERIAL. Eight specimens (all microconchs).

STRATIGRAPHICAL RANGE. Upper Kimmeridgian, Pectinatus Zone (middle part), from 19 ft. below, to 6 ft. above the Freshwater Steps Stone Band.

DESCRIPTION. *Microconch*. Moderately evolute shell with a diameter of 68–90 mm. Diameter of the umbilicus 22–30 mm. There is good agreement with Buckman's figures in all respects. The horn is long and varies from 15 to 39 mm. in length.

No macroconchs have been found at this horizon in Dorset (see below).

REMARKS. *K. cornutifer* Buckman is finer ribbed than *K. nasutus* Buckman. However, there is a complete transition in the Dorset specimens between these two forms. The *cornutifer* type occurs in the lower part, and the *nasutus* type in the upper part of the range of this species in Dorset. In the almost complete absence of macroconchs in collections from this horizon in Dorset, it is not possible to refer this species to one of the known macroconch species of *Pectinatites*. *P. pectinatus* (Phillips) occurs together with this species at Swindon and in the Oxford region, so that it may well be the macroconch of *P. cornutifer*.

***Pectinatites (Pectinatites) naso* (Buckman)**

(Pl. 32)

1926 *Keratinites naso* Buckman, pl. 652.

MATERIAL. Three specimens, all plaster casts, (two macroconchs, one microconch).

HORIZON. Ten feet above the Freshwater Steps Stone Band. Upper Kimmeridgian, middle Pectinatus Zone.

DESCRIPTION. *Macroconch*. Fairly evolute shell with a diameter of 130–138 mm. The diameter of the umbilicus is 50–54 mm. The figured specimen (C.73452) which has a diameter of 138 mm. and an umbilical diameter of 54 mm. has 40 primary ribs on the last whorl. At 25 mm. diameter there are about 45 ribs; at 30, 46; 35, 47; 40, 49; 45, 47; 50, 45.

The ribs on the inner whorls are rectiradiate at the umbilical shoulder, then curve forwards to become quite strongly prorsiradiate. The point of bifurcation of the ribs is high on the whorl-side.

On the outer whorl, just over half of which is preserved on the figured specimen, the primary ribs become stronger and more widely spaced. They branch fairly low on the whorl-side, giving rise to two or three secondary ribs. There are very occasional simple and intercalatory ribs.

The peristome is simple.

Microconch. The microconch (C.73453) is very similar to those figured by Buckman (pls. 652, 652a).

The Dorset specimen is 91 mm. in diameter, and has an umbilical diameter of 31 mm. There are an estimated 47 primary ribs on the last whorl. The preservation of the inner whorls is not good, and the following rib densities are only approximate: at 20 mm. 42 ribs; 25, 44; 30, 44.

The ribs on the inner whorls are similar in style to those of the macroconch. The umbilical seam uncoils over the last half whorl. On the outer whorl the ribs become rather suddenly more coarse half a whorl from the aperture. This last half whorl appears to correspond to the length of the body-chamber (to judge by differences in the degree of crushing). Buckman's specimens, too, have a body-chamber half a whorl in length.

On the last half whorl the primary ribs become more widely spaced; their point of furcation is lower on the whorl-side than on the inner whorls, and the angle of furcation increases. Most of the ribs on the body-chamber are bifurcate, but there are occasional unbranched primary ribs.

The peristome bears a horn which is 21 mm. long.

REMARKS. This species is readily distinguishable from *P. cornutifer* described above by the more coarsely ribbed body-chamber of the microconch.

The macroconch is considerably more coarsely ribbed than the macroconch of *P. pectinatus*.

Subfamily **DORSOPLANITINAE** Arkell 1950

Genus **PAVLOVIA** Ilovaisky 1917

Subgenus **PARAVIRGATITES** Buckman 1922

Pavlovia (Paravirgatites) cf. ***paravirgatus*** (Buckman)

(Pl. 33)

1922 *Paravirgatites paravirgatus* Buckman, pl. 353.

MATERIAL. One specimen C.73454.

HORIZON. Ten feet above the Freshwater Steps Stone Band. Upper Kimmeridgian, *Pectinatus* Zone (middle part).

DESCRIPTION. The single poorly preserved specimen has a diameter of 146 mm. and an umbilical diameter of 66 mm. There are 28 primary and an estimated 55 secondary ribs on the last whorl.

REMARKS. The specimen agrees closely with Buckman's figure in all respects except size. The holotype is about 220 mm. diameter. The general similarity and the similar horizon (Shotover Grit Sands) leave little doubt of the affinities of the Dorset specimen to Buckman's holotype.

V. EVOLUTION OF THE AMMONITES

The possible origin of the genus *Pectinatites* from an ataxioceratid stock has been discussed earlier (p. 22). Within the genus three subgenera are recognized and it is possible to follow in these subgenera various evolutionary trends.

The subgenus *Arkellites* first appears at the base of the *Elegans* Zone where it is represented by specimens referable to *P. (A.) primitivus*. *Arkellites* is characterized by more or less equicostate ribbing of the shell. This feature appears in the four species of the subgenus hitherto described. The macroconchs remain basically similar in rib style and ornamentation throughout the succession. In the microconchs, however, the tendency is for the horn to become much more prominent. *P. (A.) primitivus* has a weak ventral peristomal inflation, but all the later species have a well-developed true horn. The youngest species of *Arkellites* hitherto recorded, *P. (A.) hudlestoni*, shows a general similarity to these earlier species, and the conclusion is drawn that this subgenus was a fairly conservative one. There are as yet no species recorded from the *Wheatleyensis* Zone which can with certainty be placed in this subgenus, so that the connection between *P. (A.) hudlestoni* and earlier species of the subgenus is not known. However, *Paravirgatites kimmeridgensis* Neaverson (1925 : 33, pl. 4, fig. 4) has a rib density on its inner whorls close to that of *P. (A.) hudlestoni*, and may belong to this subgenus. The author cannot accept Neaverson's placing of his species in Buckman's genus *Paravirgatites*. The holotype shows the rib style, rib density and development typical of *Arkellites*, which is entirely different from the sharp regular bifurcate ribbing characteristic of the pavlovids. It is to be expected that the *Wheatleyensis* Zone will ultimately yield species which can definitely be assigned to the subgenus *Arkellites*.

The subgenus *Virgatosphinctoides* which appears in Dorset about a third of the way up the *Elegans* Zone could have been derived from *P. (A.) primitivus* (see p. 33). Unlike *Arkellites*, from which it probably arose, *Virgatosphinctoides* evolved rapidly. The horn of the microconch, represented by a ventral peristomal inflation in *P. (V.) elegans*, becomes a true horn by the top of the *Elegans* Zone (*P. (V.) elegans corniger*). Thereafter, the horn development becomes more pronounced, particularly in the *Hudlestoni* Zone. There are some species, however, (e.g. *P. (V.) woodwardi*) in which the horn development is not so pronounced. Considering next the macroconchs, the tendency seen is for the degree of varicostation of the shell to become more pronounced. Associated with this is the increase in the numbers of polygyrate ribs on the body-chamber. This trend continues with the appearance of virgatome ribbing in the *Wheatleyensis* Zone. Some later forms from the *Hudlestoni* Zone (e.g. *P. (V.) donovani*) show, to some extent, a reversal of this trend, and the loss of the truly virgatome rib type.

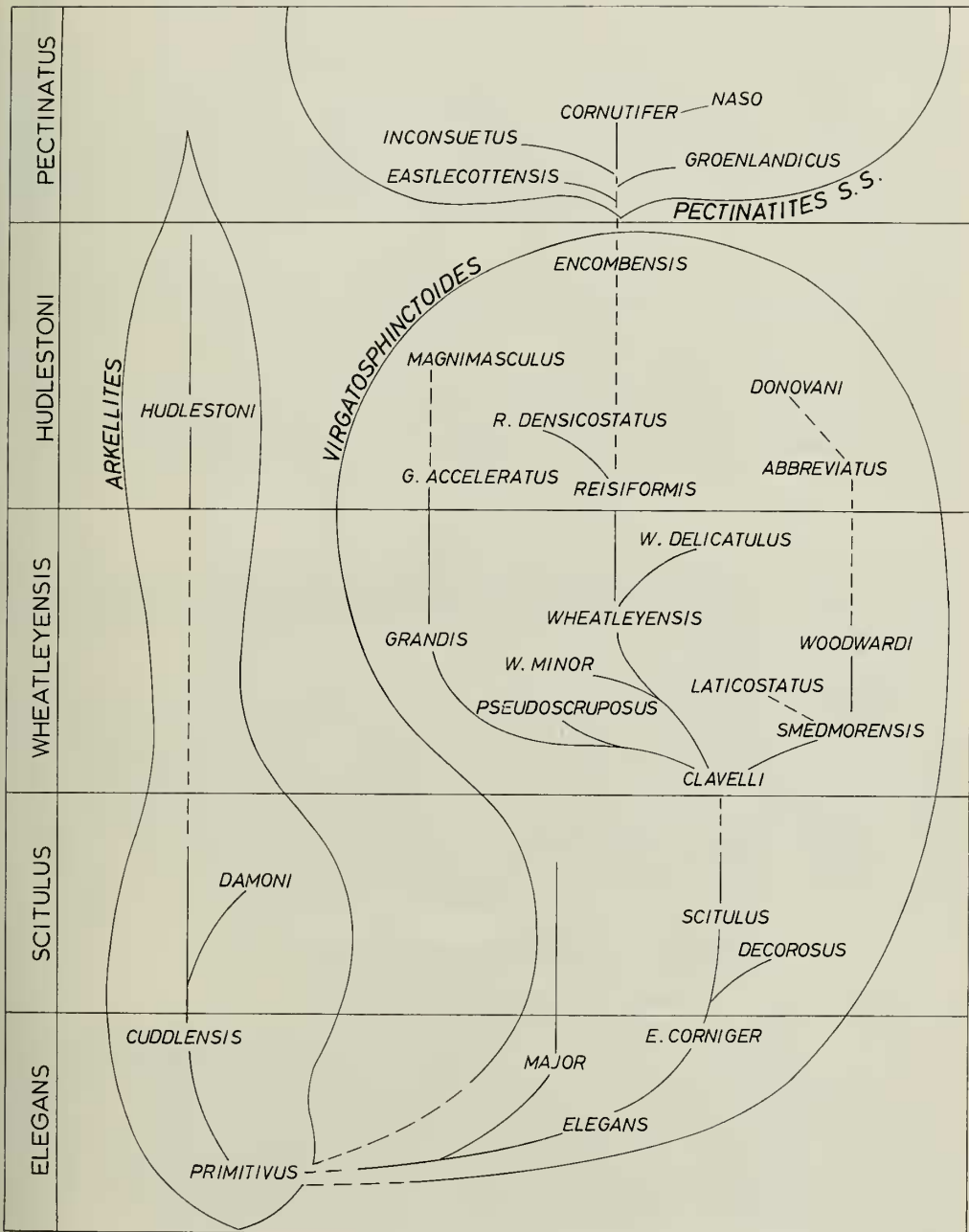


FIG. 8. Possible phylogenetic relationships of species of *Pectinatites*.

The origins of the subgenus *Pectinatites* are almost certainly to be found in the subgenus *Virgatosphinctoides*. However, the actual point of origin is not clear. *Pectinatites* may be derived from such a form as *P. (V.) encombensis*, which has a finely ribbed shell, a microconch with a well-developed horn, and an absence of virgatotome ribs on the macroconch. Alternatively, the subgenus may have been derived from *Virgatosphinctoides* earlier, perhaps as early as the Wheatleyensis Zone. In *Pectinatites* the main trends observed, as far as the lower part of the Pectinatus Zone goes, appear to be the tendency for the ribs to bifurcate low on the whorl-side, and for the microconch horn to increase in length, reaching almost 40 mm. in *P. (P.) cornutifer*.

Homeomorphy occurs within the genus *Pectinatites*, particularly between species of the subgenera *Virgatosphinctoides* and *Pectinatites*. However, the homeomorphy always seems to appear in only one sex, and not in both sexes together.

Text-fig. 8 shows diagrammatically the possible relationships between the known species of the genus. It is not, of course, to be expected that this can represent an entirely complete picture. In particular, knowledge is scant at the base of the Elegans Zone, the upper part of the Scitulus Zone, and the lowermost Pectinatus Zone.

VI. THE AMMONITE ZONES

As a result of detailed collecting from the Kimmeridge section, the position of several species of ammonites, described from other areas, has been established for the first time. This has necessitated considerable modification of the existing table of zones (see Text-fig. 9).

Since the range of many species is known fairly accurately, it is proposed to set up a sub-zonal scheme, should this prove possible, at a future date. As a prerequisite for this, however, detailed knowledge of the ammonite faunas over a large area is considered necessary. Unfortunately the Oxford and Swindon areas, which could have yielded much from careful collecting, are now devoid of good, or even adequate, exposures of Upper Kimmeridge Clay. The sections in Yorkshire and Sutherland may, however, provide good information, particularly on the lower zones.

At this time, therefore, no further refinement than zonal subdivision is attempted.

Pectinatites (Virgatosphinctoides) elegans Zone

INDEX SPECIES. *Pectinatites (Virgatosphinctoides) elegans*.

This new zone is proposed for the beds between the thin cementstone band (Bed no. 42) and the Yellow Ledge Stone Band (Bed no. 36) of the Kimmeridge section.

This new zonal index replaces a zone based on species of the genus *Gravesia* which were first used for zonal subdivision of the Kimmeridge Clay by Salfeld. After his discovery in Dorset of species of ammonites, for which he proposed the genus, he set up two zones, for the shales between the Maple Ledge Stone Band (Arkell 1947 : 73) and the Yellow Ledge Stone Band, with species of *Gravesia* as their index fossils. He proposed an upper zone of *Gravesia irius* and a lower one of *Gravesia gravesiana* (Salfeld 1913).

PROPOSED ZONES	SALFELD 1913	NEAVERSON 1925	ARKELL 1956
PECTINATITES (PECTINATITES) PECTINATUS	PERISPINCTES PALLASIANUS	PECTINATITES	PECTINATITES PECTINATUS
PECTINATITES (ARKELLITES) HUDLESTONI	VIRGATITES	PECTINATUS	SUBPLANITES WHEATLEYENSIS
PECTINATITES (VIRGATOSPHINCTOIDES) WHEATLEYENSIS		VIRGATOSPHINCTOIDES NODIFERUS	SUBPLANITES GRANDIS
PECTINATITES (VIRGATOSPHINCTOIDES) SCITULUS	MIATSCHKOVENIS	VIRGATOSPHINCTOIDES WHEATLEYENSIS	SUBPLANITES SPP. ? VIMINEUS
PECTINATITES (VIRGATOSPHINCTOIDES) ELEGANS	GRAVESIA IRIUS ----- GRAVESIA GRAVESIANA	GRAVESIA ZONES -----	GRAVESIA GIGAS ----- GRAVESIA GRAVESIANA
A U L A C O S T E P H A N U S Z O N E S			

FIG. 9. Zones of the lower part of the Upper Kimmeridge Clay.

Salfeld did not draw any junction between these two zones, and the specific identity of his specimens has long been in doubt. Arkell (1947 : 76) reported that he had seen Salfeld's specimens in Göttingen in 1937, but did not comment upon their identity. He called these two zones merely the *Gravesia* spp. zones (1947 : 67), and raised the lower limit of the zones in Dorset up to the unnamed cementstone band at the foot of Hen Cliff (about 65 ft. higher in the succession).

Later Arkell (1956 : 21) divided these Hen Cliff shales into an upper *Gravesia gigas* Zone and a lower *Gravesia gravesiana* Zone. Again, no boundary between these zones was fixed.

Arkell's raising of the upper limit of the *Aulacostephanus* Zones is justified by the occurrence of this genus up to about 15 ft. below the thin cementstone band referred to above. This band also marks the first appearance of specimens of *Pectinatites* (*Arkellites*), which are fragmentary and poorly preserved, but are probably close to *P. (A.) primitivus*.

The genus *Gravesia* is exceptionally rare in Dorset, and since 1913 only seven specimens of the genus have been found (three by Spath, two of which are in the British Museum, and one in the Geological Survey Museum; and four by the author). Of these ammonites, five are specimens of *Gravesia gigas* and have been found between 40 and 52 ft. below the Yellow Ledge Stone Band. The other two are referred to *Gravesia gravesiana* and came from eight feet below and six feet above the Yellow Ledge Stone Band (i.e. higher than any previously recorded specimens). No known *Gravesia irius* has been found since Salfeld's report of its abundant occurrence in 1913.

Whether or not *Gravesia irius* does in fact occur at Kimmeridge, it is clear that *Gravesia gravesiana* is restricted to beds higher than those yielding *Gravesia gigas*.

It is thus proposed to set up this zone based on a species of *Pectinatites*, since species of this genus are common in these beds in Dorset. This obviates any difficulty over fixing of boundaries of zones based on extremely rare index fossils, and since species of *Pectinatites* occur in this zone in Yorkshire (whereas *Gravesia* does not) there should in future be no ambiguity as in the past.

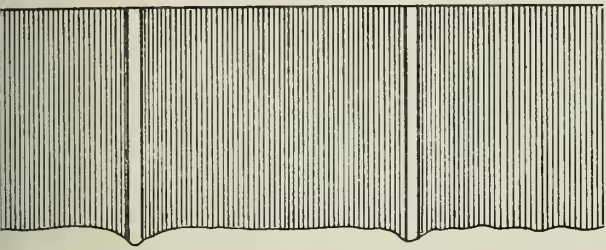
The base of the zone is fixed above the highest occurrence of *Aulacostephanus*, and at the earliest occurrence of *Pectinatites*. *P. (Arkellites) primitivus* occurs from the base of the zone into the upper part. *P. (V.) elegans* appears below the middle of the zone and ranges into the upper part, where it is replaced by *P. (V.) elegans corniger*. *P. (Arkellites) cuddlensis* occurs in the top 18 ft. of the zone. The top of the zone corresponds to the highest occurrence of *P. (V.) elegans corniger*. *Gravesia gigas* occurs just below the middle of the zone, *G. gravesiana* ranges from the highest part of the zone into the base of the succeeding Scitulus Zone.

***Pectinatites (Virgatosphinctoides) scitulus* Zone**

INDEX SPECIES. *Pectinatites (Virgatosphinctoides) scitulus* sp. nov.

This new zone is proposed for the shales between the Yellow Ledge Stone Band and the Grey Ledge Stone Band in the Dorset succession. This thickness of 90 ft. includes the Lower Cattle Ledge Shales (up to Cattle Ledge), and the Upper Cattle Ledge Shales (between Cattle Ledge and Grey Ledge).

PECTINATUS



MIDDLE
WHITE STONE
BAND

FRESHWATER
STEPS
STONE BAND

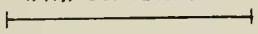
Pectinatites (Pectinatites) inconsuetus

I

P.(P.) naso

I

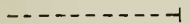
P.(P.) cornutifer



P.(P.) groenlandicus

H

P.(P.) eastlecottensis



Pavlovia (Paravirgatites) paravirgatus

H

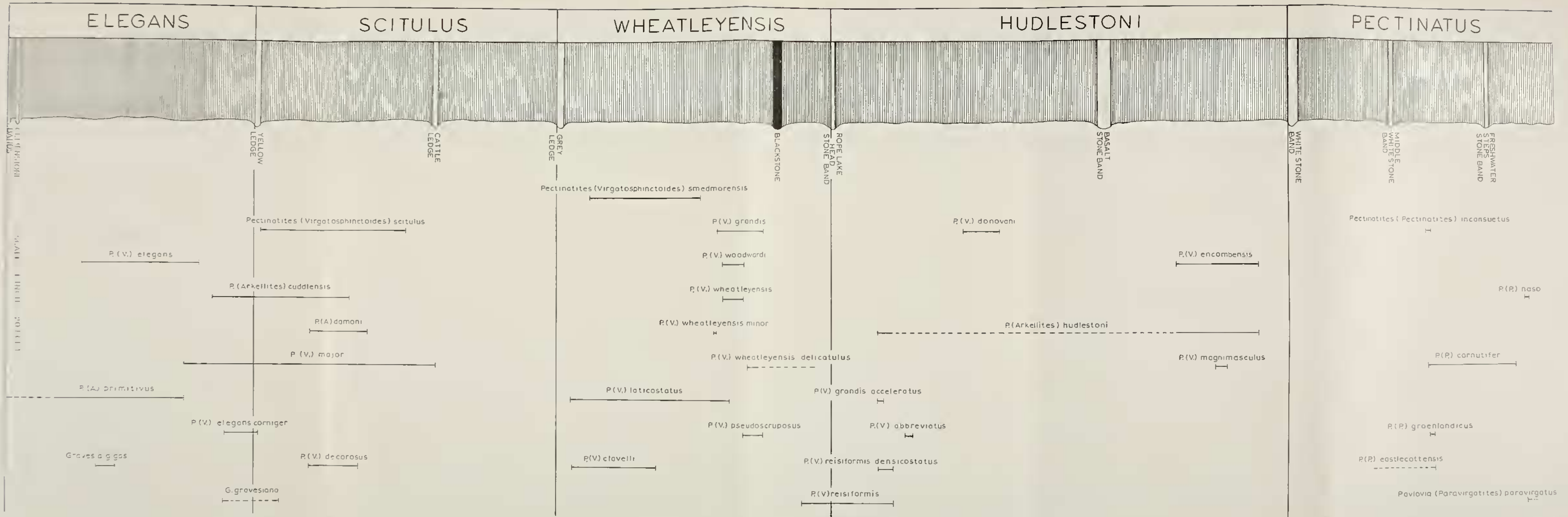


FIG. 10. Stratigraphical ranges of the ammonites from the lower part of the Upper Kimmeridge Clay.

The Upper Cattle Ledge Shales have hitherto failed to yield ammonites and are provisionally included in this zone, pending ammonite evidence from Dorset or elsewhere.

Pectinatites (Virgatosphinctoides) scitulus first appears at the base of the zone, and ranges to about the middle of the ammonite bearing strata. *Gravesia gravesiana* occurs in the lowest six feet of the zone at Kimmeridge. *Exogyra virgula* ranges up to 27 ft. above the Yellow Ledge Stone Band. *Lingula ovalis* reaches its maximum abundance near the base of the zone.

This zone corresponds to the lower part of Salfeld's *Virgatites miatschkovens* Zone, the lower part of Neaverson's *Virgatosphinctoides wheatleyensis* Zone, and the *Subplanites ? vimineus* Zone of Spath (Arkell 1956 : 21).

Pectinatites (Virgatosphinctoides) wheatleyensis Zone

INDEX SPECIES. *Pectinatites (Virgatosphinctoides) wheatleyensis* (Neaverson).

This zone, which in the Dorset succession is represented by the beds between the Grey Ledge Stone Band and the Rope Lake Head Stone Band, corresponds to part of the *Virgatites miatschkovens* Zone of Salfeld (1913); the *Pseudovirgatites* Zone of Lamplugh, Kitchin & Pringle (1922); the lower part of the *Pectinatus*, the *Nodiferus* and the upper part of the *Wheatleyensis* Zone of Neaverson (1925); and to all but the uppermost part of the *Grandis* Zone of Arkell (1956).

The position of *Pectinatites (Virgatosphinctoides) wheatleyensis* (Neaverson) has hitherto been very uncertain in the Dorset succession. In Oxfordshire, it occurs associated with *P. (V.) woodwardi*, *P. (V.) wheatleyensis delicatulus* and *Sphinctoceras*. The same faunal association (without *Sphinctoceras*), but with *P. (V.) grandis* and *P. (V.) pseudoscruposus* in addition, is found in Dorset in the shales immediately below the Blackstone.

At the base of the zone ammonites of the subgenus *Virgatosphinctoides* are represented by *P. (V.) clavelli*, *P. (V.) smedmorensis* and *P. (V.) laticostatus*; the latter two species ranging up to the middle of the zone.

The crinoid *Saccocoma* ranges in Dorset through 13 ft. of Beds in the upper part of the Zone.

The top of the Zone corresponds to the highest occurrence of *P. (V.) wheatleyensis delicatulus* and the earliest occurrence of *P. (V.) reisiiformis*.

The zone is represented in the Oxford district by the Wheatley Nodule Bed, and is present on the Yorkshire coast.

Pectinatites (Arkellites) huddlestoni Zone

INDEX SPECIES: *Pectinatites (Arkellites) huddlestoni* sp. nov.

This new zone is proposed for the beds between the Rope Lake Head Stone Band and the White Band in the Kimmeridge succession. It corresponds to the upper part of Salfeld's *Virgatites miatschkovens* Zone, part of Neaverson's *Pectinatus* Zone, and to the *Wheatleyensis* Zone and topmost part of the *Grandis* Zone of Arkell. At the base of the zone *Pectinatites (Virgatosphinctoides) reisiiformis* occurs, and a little above the base is associated with *P. (A.) huddlestoni* which ranges through-

out the zone. The middle part of the zone is characterized by *P. (V.) donovani* and the upper part by *P. (A.) hudlestoni*, *P. (V.) encombensis* and *P. (V.) magninasculus*.

Inland this zone may be represented by the Shotover Fine Sands and the Lower Cemetery Beds in the Oxford and Swindon areas respectively. There is no palaeontological evidence to support this correlation directly, however, and the zone, if present is certainly very much attenuated. It is probably present in Yorkshire.

Pectinatites (Pectinatites) pectinatus Zone

INDEX SPECIES. *Pectinatites (Pectinatites) pectinatus* (Phillips).

This zone corresponds to the *Perisphinctes pallasianus* Zone of Salfeld, the upper part of the *Pectinatus* Zone of Neaverson, and the *Pectinatus* Zone of Arkell.

In Dorset the lower boundary of the zone is taken at the White Stone Band which marks the upper limit of the range of the subgenus *Virgatosphinctoides*, and the upper boundary below the first occurrence of *Pavlovia* s.s. The upper part of this zone has not yet been fully investigated in Dorset.

The earliest species recorded in Dorset is *Pectinatites (Pectinatites) eastlecottensis*; this species is recorded together with such species as *P. (P.) cornutifer* and *P. (P.) naso* from the Shotover Grit Sands in the Oxford region. No detailed stratigraphical collections have been made from these beds in the Oxford region, however, and it may be that they are not in fact completely synchronous, as published faunal lists suggest. In Dorset there is little overlap of the ranges of these species (Text-fig. 10), and it is to be expected that detailed collecting would show similar relationships between the various ranges of species in the Oxford area, where the succession is considerably thinner.

VIII. CORRELATIONS

(a) GREAT BRITAIN

The Upper Kimmeridge Clay is exposed in only a limited number of localities in Britain, and of these few exposures most are now very poor. The majority of the published faunal lists from these exposures are now outdated, and nowhere have collections been made in detail comparable to that recently carried out in Dorset. For these reasons, correlations with other areas of Britain cannot, in most cases, be established with a great deal of accuracy at present. It is hoped that future collecting will remedy this deficiency.

Two areas of Britain where the succession of the Kimmeridgian faunas have been well known for some time are the Swindon and Oxford regions. Correlations with these areas are shown in Text-fig. 11. In both these areas the succession is considerably attenuated. The ammonites, however, are generally better preserved than those in Dorset and have therefore attracted considerably more attention in the past. It was primarily on information obtained from the Oxford area that Neaverson (1925) set up his zonal scheme for the Upper Kimmeridge Clay. It is now possible for the first time to show the true stratigraphical position of many of Neaverson's species in the complete Dorset succession. As a direct result of this, it appears likely that there

ZONES	KIMMERIDGE	SWINDON	OXFORD
<i>PECTINATITES</i> (<i>PECTINATITES</i>) <i>PECTINATUS</i>	BEDS ABOVE THE WHITE STONE BAND UP TO 65 FEET ABOVE THE FRESHWATER STEPS STONE BAND 130 FEET	SHOTOVER GRIT SANDS UPPER CEMETERY BEDS, <i>PARS</i> 35-45 FEET	SHOTOVER GRIT SANDS 15-20 FEET
<i>PECTINATITES</i> (<i>ARKELLITES</i>) <i>HUDLESTONI</i>	BEDS BETWEEN THE ROPE LAKE HEAD STONE BAND AND THE WHITE STONE BAND 134 FEET	? SHOTOVER FINE SANDS (LOWER CEMETERY BEDS)	? SHOTOVER FINE SANDS 4 FEET
<i>PECTINATITES</i> (<i>VIRGATOSPHINCTOIDES</i>) <i>WHEATLEYENSIS</i>	BEDS BETWEEN THE GREY LEDGE STONE BAND AND THE ROPE LAKE HEAD STONE BAND 83 FEET	?NON-SEQUENCE CLAYS OF HILL'S BRICKYARD	NON-SEQUENCE CLAYS WITH NODULES 10-15 FEET
<i>PECTINATITES</i> (<i>VIRGATOSPHINCTOIDES</i>) <i>SCITULUS</i>	CATTLE LEDGE SHALES 90 FEET	? NON SEQUENCE	MAJOR
<i>PECTINATITES</i> (<i>VIRGATOSPHINCTOIDES</i>) <i>ELEGANS</i>	HEN CLIFF SHALES 73 FEET	CLAYS OF BAZZARD'S UPPER PIT ?NON-SEQUENCE	NON-SEQUENCE
<i>AULACOSTEPHANUS</i> ZONES	MAPLE LEDGE SHALES	CLAYS OF BAZZARD'S MIDDLE PIT	SHALES WITH <i>EXOGYRA VIRGULA</i>

FIG. 11. Correlation of the lower part of the Upper Kimmeridge Clay of Kimmeridge with that of the Swindon and Oxford areas.

is a previously undetected non-sequence in both the Oxford and Swindon areas, between the *Pectinatus* and *Wheatleyensis* Zones, corresponding to the *Hudlestoni* Zone. This zone may be represented in part, however, by the Shotover Fine Sands.

Between the Lower and Upper Kimmeridge Clay there is a major non-sequence in the Oxford area. Above the *Aulacostephanus* Zones are beds yielding *Pectinatites* (*Virgatosphinctoides*) *wheatleyensis*. There are no known records of fossils indicative of the *Elegans* or *Scitulus* Zones. At Swindon, however, the position is different. Chatwin & Pringle (1922 : 165) mention that the Hudleston collection contains a specimen of *Gravesia* from Swindon, and it is therefore possible that the succession in this region, though attenuated, is fairly complete.

In Yorkshire the Kimmeridge Clay is exposed beneath the Lower Cretaceous rocks which rest unconformably on it at Speeton. The Kimmeridge Clay here is little known palaeontologically. The highest horizon recorded in this section is the *Wheatleyensis* Zone, but a specimen sent to me by Dr. P. Kaye from the highest beds of the Kimmeridge Clay, is undoubtedly close to *Pectinatites* (*P.*) *proboscide* (Buckman), requiring correlation with the *Pectinatus* Zone. There appears no reason to believe that the Yorkshire succession is not complete up to this latter zone. The *Elegans* Zone in Yorkshire is unlikely to yield *Gravesia* since the presence of this genus has not been confirmed north of Swindon.

In Sutherland, the lowest part of the Upper Kimmeridge Clay appears to be present, to judge from the account by Bailey & Weir (1932). Above the *Aulacostephanus* zones they recorded species of *Lithacoceras* indicative of the *Gravesia* zones, and evidence for the lower part of the *Virgatites* zone. I interpret this evidence as showing that the *Elegans* and possibly *Scitulus* Zones are present. The record of *Lithacoceras* presumably refers to a species of *Pectinatites* perhaps of the *Elegans* Zone. This area is one from which collecting is planned in the future.

(b) THE BOULONNAIS

The Upper Kimmeridgian of the Boulonnais shows similarities to the Kimmeridgian of Britain. It is remarkable chiefly for the development of phosphatic nodule beds at several horizons. The succession below is based on descriptions by Pruvost (1924), with modifications after Arkell (1956 : 42) and revised determinations of the ammonite names.

Bed. No. (Pruvost) 1924)

Ph. 3. Tour Croi Nodule Bed with phosphatized ammonites:

Pavlovia rotunda, *P. leblondi*, *Pectinatites* (*Pectinatites*) *devillei*, *P.* (*P.*) *boidini*, *Pectinatites* (*P.*) *rarescens*, *P.* (*P.*) *opulentus*.

5. Clay 26 ft.: *P.* (*P.*) *devillei*, *P.* (*P.*) *boidini*, *P.* (*P.*) sp., *Pavlovia lydianites*, *Exogyra dubiensis*.

Ph. 2. Phosphatic nodule Beds: undescribed ammonites:

4. Clay 6 ft. 6 ins.: undescribed ammonites, *Lingula ovalis*, *Discina latissima*, *Modiola autissiodorensis*, *Anomia laevigata*.

- Ph. 1. La Rochette Nodule bed: *Pectinatites (Virgatosphinctoides) pringlei*, *P. (V.)* spp.
 3. Clays 26 ft. *Discina latissima*, *Pectinatites (Virgatosphinctoides)* spp.
 2. Gres de la Creche (upper part) 16 ft.: *Pectinatites (Virgatosphinctoides)* sp.
 1. Gres de la Creche (lower part) 32 ft. 6 ins. *Gravesia portlandica* (? = *G. gigas*),
 " *Perisphinctes* " *bleicheri*, *Trigonia pellati*, *Exogyra virgula*.

Aulacostephanus Zones.

Again the ammonite fauna of these beds is not well known, but on the basis of the recorded species and the associated fauna, several correlations may be suggested.

Bed 1 corresponds to the Elegans Zone. *Gravesia portlandica* (de Loriol) is probably a junior synonym of *G. gigas* (Zieten). *Trigonia pellati* and *Exogyra virgula* also occur in this zone in Dorset.

Beds 2-4 probably correspond to the Scitulus, Wheatleyensis and Hudlestoni Zones. *Pectinatites (Virgatosphinctoides) pringlei* (horizon Ph. 1) is close to *P. (V.) wheatleyensis*, and is probably, therefore, from the mid-Wheatleyensis Zone.

Bed 5 appears to correspond to the upper part of the Pectinatus Zone, and the Tour Croi Nodule Bed to the Rotundum Zone.

(c) EAST GREENLAND (MILNE LAND)

The Kimmeridgian fauna of Greenland were the subject of papers by Spath (1935, 1936). He described therein collections made on expeditions led by Dr. Lauge Koch.

The Upper Kimmeridgian succession there (Spath 1936 : 163) is:

- Pavlovia* Beds. 150 ft.
Pectinatites Beds. 150 ft.
 Unfossiliferous Shales. 120 ft.
 Band of crushed Perisphinctids.

The *Pectinatites* Beds correspond to the Pectinatus Zone of Dorset. Specific identity is established with Dorset in two cases.

The band of crushed Perisphinctids yielded three specimens which Spath identified tentatively as *Subdichotomoceras?*, *Subplanites?* (*Virgatosphinctoides?*), and *Subplanites?* (Spath 1936, pl. 1). The latter two specimens appear from the plate to resemble forms from the Wheatleyensis Zone, and are probably to be correlated with this zone. The unfossiliferous beds between these two points of correlation probably representing the Hudlestoni Zone of Dorset. No fauna to be correlated with Elegans or Scitulus Zones is recorded from East Greenland.

(d) SOUTHERN GERMANY (FRANCONIA)

In the southern part of Europe the ammonite fauna of the Upper Jurassic rocks becomes markedly different from that of North-west Europe, above the Lower Kimmeridgian. To these rocks equivalent to the Upper Kimmeridgian and Portlandian Stages of North-west Europe the stage name " Tithonian " is generally applied.

SUGGESTED CORRELATIONS (MODIFIED AFTER COPE AND ZEISS 1964)		CORRELATIONS BY ARKELL 1956	
GLAUCOLITHITES GOREI	NEUBERG BEDS	CORRELATIONS BETWEEN THE UPPER KIMMERIDGIAN AND LOWER PORTLANDIAN OF BRITAIN AND THE LOWER TITHONIAN OF GERMANY	
ZARAIISKITES ALBANI			
PAVLOVIA PALLASIOIDES			
PAVLOVIA ROTUNDA			
PECTINATITES (PECTINATITES) PECTINATUS	RENNERTSHOFEN BEDS	NEUBERG BEDS	PECTINATUS ?
PECTINATITES (ARKELLITES) HUDDLESTONI		RENNERTSHOFEN BEDS	SUBPLANITES SPP.
PECTINATITES (VIRGATOSPHINCTOIDES) WHEATLEYENSIS	USSELLTAL BEDS	UPPER ULMENSIS BEDS	?
PECTINATITES (VIRGATOSPHINCTOIDES) SCITULUS	MOERNSHEIM BEDS		
PECTINATITES (VIRGATOSPHINCTOIDES) ELEGANS	BEDS		
		SOLENHOFEN BEDS	GRAVESIANA

FIG. 12. Correlations between the Upper Kimmeridgian and Lower Portlandian of Britain, and the Lower Tithonian of Franconia.

The area taken herein, as representative of typical Tithonian rocks, is Franconia. I have recently visited this area, and have examined large ammonite collections made by Dr. A. Zeiss of the University of Erlangen, with whom I discussed problems of correlation between the two faunal provinces. The results of these discussions were incorporated in a joint paper (Cope & Zeiss 1964).

The most firm bases for correlation are to be found between the basal and uppermost Upper Kimmeridgian and basal Portlandian, and their Franconian equivalents. In the Lower Neuberg Beds specimens of *Pavlovia* and *Zaraiskites* have recently been found. This gives good correlations with the uppermost Kimmeridgian and basal Portlandian of Dorset. The discoveries are particularly important since it means that the Kimmeridgian–Portlandian boundary can be traced into the Tithonian faunal province.

At the base of the Upper Kimmeridgian the genus *Gravesia* occurs, its vertical range in Dorset being about 60 ft. In Franconia, *Gravesia* occurs in the Moernsheim Beds where its vertical range is about 90 ft.

Between these two points where correlation can definitely be established, the faunas of the two provinces are distinct. In Britain species of *Pectinatites* are the commonest ammonites, and in Franconia species of *Subplanites*, *Lithacoceras* and *Pseudovirgatites*. As stated earlier (p. 20) *Subplanites* and *Lithacoceras* do not occur in Britain. It therefore appears that the apparent similarity between the two faunas is due entirely to the phenomenon of homeomorphy.

It is remarkable to find that some homeomorphs seem to have existed contemporaneously. Thus some ammonites of the *Pectinatites* (*Virgatosphinctoides*) *grandis* group are very close to undescribed ammonites from the Usseltal Beds. *P.* (*Virgatosphinctoides*) *reisiformis* has a very similar microconch to *Subplanites siliceus*, the apertural modifications of the two forms being the only apparent point of difference. *P.* (*Pectinatites*) *inconsuetus* has a macroconch almost identical in appearance to an undescribed species of *Pseudovirgatites*.

Such homeomorphs cannot provide correlations, but it has been found that their respective stratigraphical ranges are approximately equal in some cases. It appears that direct correlation by means of ammonites is not possible in this case, and the problem is unlikely to be solved until an area is discovered where an overlap of the faunal provinces occurs.

(e) RUSSIA (BASIN OF THE URAL AND ILEK RIVERS)

The Upper Kimmeridgian faunas of the basin of the Ural and Ilek rivers were described by Ilovaisky & Florensky (1941). The specimens they described came from the Vetlianka Sandstone, and were described as belonging to the genus *Ilovaiskya* Vialov 1940. This genus was regarded by Arkell (1957) as a junior synonym of *Subplanites* Spath 1925.

Although several of the forms figured by Ilovaisky & Florensky appear very similar to British species, and were identified as such by Arkell (1956 : 489–490), identity even at generic level with British forms cannot be established on the basis of the published plates. None of the ammonites figured by Ilovaisky & Florensky has its

peristome preserved, and thus may belong equally to *Subplanites* or its homeomorph *Pectinatites*. As no specimens similar to *Lithacoceras* were figured, it is possible that the Russian forms belong to *Pectinatites* rather than to *Subplanites*. The collection of material with peristomes intact is essential, however, for this to be established with certainty.

This problem has not been resolved in a more recent paper by Michailov (1964). He figures specimens under the names of *Subplanites* and *Pectinatites*. It may well be that in parts of Russia there is a mixture of these two faunal elements, but again the absence of peristome-bearing specimens means that such generic placings by Michailov may be incorrect.

VIII. REFERENCES

- ARKELL, W. J. 1933. *The Jurassic System in Great Britain*. xii + 681 pp., 41 pls., 97 figs. Oxford.
- 1935. On the Lower Kimmeridgian ammonite genera *Pictonia*, *Rasenia*, *Aulacostephanus* and *Ataxioceras*. *Geol. Mag.*, London, **72** : 246–257, pl. II.
- 1935–1948. A monograph of the ammonites of the English Corallian Beds. lxxxiv + 420 pp., 78 pls. *Palaeontogr. Soc. (Monogr.)*, London.
- 1946. Standard of the European Jurassic. *Bull. geol. Soc. Am.*, New York, **57** : 1–34.
- 1947. *The geology of the country around Weymouth, Swanage, Corfe, and Lulworth*. xii + 386 pp., 19 pls. (Mem. geol. Surv. U.K., London).
- 1947a. *The geology of Oxford*. vi + 267 pp., 6 pls. Oxford.
- 1950. A classification of the Jurassic ammonites. *J. Paleont.*, Tulsa, **24** : 354–364.
- 1953. Seven new genera of Jurassic ammonites. *Geol. Mag.*, London, **90** : 36–40, pl. I.
- 1956. *Jurassic Geology of the World*. xv + 806 pp., 46 pls. Edinburgh & London.
- ARKELL, W. J., KUMMEL, B. & WRIGHT, C. W. 1957. Mesozoic Ammonoidea. In *Treatise on Invertebrate Paleontology*. Part L. Mollusca 4. Cephalopoda, Ammonoidea. (Ed. by R. C. Moore). L80–L437. Kansas & New York.
- BAILEY, E. B. & WEIR, J. 1932. Submarine faulting in Kimmeridgian times in East Sutherland. *Trans. R. Soc. Edin.*, **57** : 429–467, pls. 1–3.
- BASSE, E. 1930. Contribution à l'étude du Jurassique supérieur (facies corallien) en Ethiopie et en Arabie méridionale. *Mém. Soc. géol. Fr.*, Paris (n.s.) **6** : 105–148, pls. 4, 5.
- 1952. Céphalopodes. In Piveteau, J. 1952. *Traité de Paléontologie*, **2** : 461–755, pls. 1–24. Paris.
- BERCKHEMER, F. & HÖLDER, H. 1959. Ammoniten aus dem Oberen Weissen Jura Süddeutschlands. *Beih. geol. Jb.*, Hannover, **35** : 1–135, 27 pls.
- BLAKE, J. F. 1875. On the Kimmeridge Clay of England. *Q. Jl geol. Soc. Lond.*, **31** : 196–237.
- 1880. On the Portland rocks of England. *Q. Jl geol. Soc. Lond.*, **36** : 189–236.
- 1881. On the correlation of the Upper Jurassic rocks of England with those of the Continent. Part I. The Paris Basin. *Q. Jl geol. Soc. Lond.*, **37** : 497–587.
- BLANCHET, F. 1923. La faune du Tithonique inférieur des régions subalpines et ses rapports avec celle du Jura franconien. *Bull. Soc. géol. Fr.*, Paris (4) **23** : 70–80.
- BUCKMAN, S. S. 1922–1923. *Type Ammonites*, **4** : 1–67, pls. 268A–422. London.
- 1923–1925. *Type Ammonites*, **5** : 1–88, pls. 423–576. London.
- 1925–1927. *Type Ammonites*, **6** : 1–61, pls. 528A–717B. London.
- 1927–1930. *Type Ammonites*, **7** : 1–78, pls. 31A–773A. With editorial notes by A. Morley Davies. London & Thame.
- BUCKMAN, S. S. & BATHER, F. A. 1894. Can the sexes in ammonites be distinguished? *Nat. Sci.*, London, **4** : 427–432.

- CALLOMON, J. H. 1955. The ammonite succession the Lower Oxford Clay and Kellaways Beds at Kirtlington, Oxfordshire, and the zones of the Callovian Stage. *Phil. Trans. R. Soc., London*, **239**, B: 215-264, pls. 2, 3.
- 1957. Field meeting in the Oxford Clay of Calvert and Woodham Brick Pits, Buckinghamshire. *Proc. Geol. Ass.*, London, **68**: 61-64.
- 1961. The Jurassic System in East Greenland. In Raasch, G. O. 1961 (Editor), *Geology of the Arctic*: 258-268. Toronto.
- 1963. Sexual dimorphism in Jurassic ammonites. *Trans. Leicester lit. phil. Soc.*, **57**: 21-56, pl. 1.
- CHATWIN, C. P. & PRINGLE, J. 1922. The zones of the Kimmeridge and Portland rocks at Swindon. *Summ. Progr. Geol. Surv. Lond.*, **1921**: 162-168.
- COPE, J. C. W., SARJEANT, W. A. S., SPALDING, D. A. E. & ZEISS, A. 1964. The Kimmeridgian-Portlandian boundary. In *Colloque du Jurassique, Luxembourg 1962. Volume des comptes rendus et mémoires*, Luxembourg: 933-936.
- COPE, J. C. W. & ZEISS, A. 1964. Zur Parallelisierung den englischen Oberkimmeridige mit dem fränkischen Untertithon (Malm Zeta). *Geol. Bl. Nordost-Bayern*, Erlangen, **14**: 5-14.
- DACQUÉ, E. 1905. Beiträge zur Geologie des Somalilandes. 2 Oberer Jura. *Beitr. Paläont. Geol. Öst.-Ung.*, Wien, **17**: 119-160, pls. 14-18.
- DAMON, R. 1884. *Geology of Weymouth, Portland, and the coast of Dorsetshire, from Swanage to Bridport-on-the-Sea: with natural history and archaeological notes.* 2nd (revised) ed. xii + 250 pp. London.
- 1888. *A supplement to the Geology of Weymouth.* 2nd. (revised) ed. 20 pls. London.
- DONOVAN, D. T. 1957. The Jurassic and Cretaceous Systems in East Greenland. *Meddr. Grønland*, Copenhagen, **155**: 1-214, pls. 1-4.
- DONZE, P. & ENAY, R. 1961. Les céphalopodes du Tithonique inférieur de la Croix-de-Saint-Concours près Chambéry (Savoie). *Trav. Lab. Géol. Univ. Lyon* (n.s.) **7**: 1-236, pls. 1-22.
- DOUVILLÉ, R. 1910. Un *Virgatites* du Caucase occidental; origine méditerranéenne du genre; *Ataxioceras*, *Pseudovirgatites* et *Virgatosphinctes*. *Bull. Soc. géol. Fr.*, Paris (4) **10**: 730-739, 1 fig.
- DUMORTIER, E. & FONTANNES, F. 1876. *Description des ammonites de la zone à Ammonites tenuilobatus de Crussol (Ardèche) et de quelques autres fossiles jurassiques nouveaux ou peu connus.* 159 pp., 19 pls. Paris.
- DUTERTRE, A. P. 1926. Contribution à l'étude paléontologique du Portlandien du Boulonnais. *Annls Soc. géol. N.*, Lille, **51**: 240-249.
- 1927. Remarques sur la position stratigraphique de quelques ammonites du Portlandien moyen du Boulonnais. *C. r. somm. Séanc. Soc. géol. Fr.*, Paris (4) **27**: 36-37.
- FAVRE, E. 1877. La zone à *Ammonites acanthicus* dans les Alpes de la Suisse et de la Savoie. *Abh. schweiz. paläont. Ges.*, Zürich, **4**: 1-112, pls. 1-9.
- FREBOLD, H. 1928. Das Festungsprofil auf Spitzbergen, Jura und Kreide. *Skr. Svalbard Ishavet*, Oslo, **19**: 183-201.
- GEYER, O. F. 1961. Über die älteste virgatipartite Berippung der Perisphinctidae (Cephalopoda). *Paläont. Z.*, Stuttgart, **35**: 90-94.
- 1961a. Monographie der Perisphinctidae des unteren Unter-Kimeridgium (Weisser Jura, Badenerschichten) im süddeutschen Jura. *Palaeontographica*, Stuttgart, **117**, A: 1-157, pls. 1-22.
- GLANGEAUD, P. 1897. Sur la forme de l'ouverture de quelques ammonites. *Bull. Soc. géol. Fr.*, Paris (3) **25**: 99-107.
- HAHN, W. 1963. Die Gattung *Gravesia* Salfeld im Oberjura Mittel- und Nordwesteuropas. *Palaeontographica*, Stuttgart, **122**, A: 90-110, pls. 9-13.
- HÖLDER, H. 1961. Über den *Ammonites ulmensis* Oppel. *Jber. Mitt. oberrhein. geol. Ver.*, Stuttgart, **43**: 113-117, pl. 5.
- HUDLESTON, W. H. 1896. In Hudleston, W. H. Mansel, O. L. & Monckton, H. W. Excursion to Swanage, Corfe Castle, Kimmeridge, etc. *Proc. Geol. Ass.*, London, **14**, 312-323.